Psychology and Human Performance

an introduction to psychology

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PSYCHOLOGY AND HUMAN PERFORMANCE

An Introduction to Psychology

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PREFACE

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We have had a number of definite aims in writing this book. First of all we wanted to provide the student with a *systematic* description of human behavior. It seemed to us that a first course in psychology should provide a framework for thinking about specific psychological facts and principles. We chose to provide this framework through a "dimensional approach" rather than by emphasizing a particular theoretical position. By this we mean that we have tried to present a useful way of classifying the varieties of behavior, with emphasis on the kinds of things human beings can do. This theme runs throughout the book.

Our impression that this approach would be useful comes also from our association with individuals who deal in practical ways with human performance, and who have become increasingly aware of the need for a useful model of man as a behaving organism. For example, the planners and designers of new industrial procedures, business processes, and military weapon systems face many problems that require them to make assumptions about what man can do and what kinds of behavior he is likely to exhibit in performing useful work. The trained psychologist may know "where to start" in dealing with these problems. But the engineer or designer frequently "doesn't know what to look for," even though there are excellent collections of specific behavioral data available in handbooks. Perhaps the most useful first question to ask, with respect to a specific human activity, is "What general class of behavioral phenomena is this?" Psychologists often consider this so fundamental that they may not commit this information to print. It was our belief that a first course in psychology could be organized in terms of an explicit categorization of human functions.

We are well aware that such categories may change with new advances in scientific knowledge, and that there is nothing peculiarly permanent about the classes of behavioral functioning we describe. But by using them, we have been able to make the attempt of tying together in a meaningful way the variety of topics appropriate to introductory psychology, as well as certain fields of application of psychological knowledge.

A second theme we have had in mind in writing the book is an emphasis on the scientific character of psychology. We have tried to impart the notion that the subject-matter of human behavior can appropriately be viewed as science, and that the investigator uses the methods of science in obtaining these facts. Although we do not attempt to provide the student with a detailed knowledge of specific techniques for the study of behavior, we emphasize that sound scientific knowledge about behavior is to be obtained within a framework of experimental science. Results of such studies are therefore frequently presented in graphic form, which is a familiar one to psychologists and to all students of science. There are many graphs in the book.

Some teachers may want to supplement the text with additional readings or with additional material on measurement techniques and methods. We have kept in mind that the overwhelming proportion of students in introductory courses are not majors in psychology. Therefore, we have not emphasized "how to be a psychologist" any more than a first course in biology emphasizes "how to be a biologist."

As the title suggests, it is our aim to provide the student with knowledge of *human* behavior. Of course, this does not mean that we avoid discussing animal behavior or the findings and generalizations which psychologists have derived from many excellent animal studies. It does mean that data from animal studies are always used specifically to illuminate human behavior. Furthermore, the emphasis on human behavior brings in its wake some subordinate emphases in content which the reader will readily appreciate. Some findings appear to be of more immediate relevance to the understanding of human behavior than do others. For example, our emphasis throughout is on what is known about human performance; we continually emphasize the interaction of the individual with his environment, but we do not stress problems of the adjustment of the individual student.

Although fundamental principles are stressed throughout, there is also a practical emphasis to this book. At least implicitly, it offers the point of view that psychological knowledge can and should be used in the planning and design of productive work enterprises that require the participation of human skills. In the final four chapters, this idea is given an expanded treatment in connection with human jobs, personnel selection, proficiency measurement, training programs, and the design of equipment and man-machine systems.

The integrated treatment has led to certain sequential features in the book. For example, the characteristics of receptors, effectors, and the nervous system are described early in the book, since this is considered fundamental to our treatment of the "basic components of the behavior system." The topic of individual differences is not treated as if it were a separate discipline; instead we have given an expanded treatment to what is now known about human abilities and we have tried to integrate this with material in such areas as learning and motivation. There is no separate chapter on "development," but the reader will find this subject treated in connection with the various abilities and with behavior functions. Although the chapters on applications of psychology are in the later part of the book, we have not hesitated to introduce research evidence from military and industrial situations early in the book. In fact, wherever possible, we have tried to compare laboratory and field studies to illustrate particular principles, especially in the treatment of such topics as motivation, human abilities, and social behavior.

On the whole, this textbook represents the subject-matter which we ourselves should like to teach, and accordingly would like to see taught, in the first course in psychology. We have tried to make psychology meaningful as a science which relates to the student's previous knowledge about human activities, as well as to his anticipated considerations of people as productive human beings. As a text for the psychology major, the book is intended as a natural precursor to a treatment of techniques and methods such as is contained in a basic text in experimental psychology. For the introductory course offered to students whose career interests are in the direction of engineering or natural science, we believe this book fills the need for a text which will engender respect for psychology as an experimental science. To an equal extent, the book should be appropriate for use in an introductory course taken by students whose interests are in careers in industry, medicine, or social science.

The *Student's Manual* designed to accompany this text contains self-test exercises, quizzes, and problems which have been coordinated chapter by chapter. In addition, it provides a very useful introductory chapter entitled "How to Study." The *Manual* may be used by the student outside of class, as a study aid, or it may be used to provide material for class exercises.

R.M.G.
E.A.F.

Princeton, New Jersey
New Haven, Connecticut
February, 1959

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PSYCHOLOGY AND HUMAN PERFORMANCE

1

INTRODUCTION: THE SCIENCE OF BEHAVIOR

This chapter introduces psychology, the science of behavior. The relation of psychology to other sciences is described. You will gain an idea of the scientific point of view towards human behavior. Some of the methods used by the psychologist to study behavior are examined. Finally the total plan of the book is outlined, to show how each succeeding chapter contributes to understanding the human behavior system and its functioning.

Psychology is the science of behavior. In its broadest sense, it is the systematic study of how living organisms respond to and adjust to the environment in which they live.

All living organisms, even plants and the lowest animals, exhibit reactions to changes in their immediate surrounding environments. Many plants grow toward sunlight, for example; single-celled animals orient themselves toward or away from the pull of gravity; moths circle a flame; a dog responds to a call from his master; a human being manages the operations of a factory. All these are examples of behavior. Some of them have explanations almost as simple as that which applies to the action of an electric motor; others are more complex than the most intricate modern electronic computer.

As a science, psychology has the aim of understanding behavior. It attempts to *predict* what a behaving organism will do under various circumstances, by determining what antecedent events are related to different forms of activity. Furthermore, it aims to *specify* the events which cause various types of behavior.

PSYCHOLOGY AND OTHER SCIENCES

Psychology occupies a unique position among sciences. It is, on the one hand, a *biological science*, having a close relationship with physiology, which deals with the functioning of systems of organs in the body. On the other hand it is one of the *behavioral sciences*, which are generally concerned with the behavior of man in society.

Generally speaking, psychology deals with the behavior of the total organism as distinguished from behavior of a part of the body. For example, the movement of a finger may be explained by physiology in terms of stimulation of muscular tissue by nerve impulses, contraction of the muscle, use of oxygen from the blood stream, and so on. But when a person *points* his finger *at* something, his act can be adequately understood only by realizing that it is a response of the total person to some preceding set of events in him and in his environment. It is behavior in this sense—of a total organism—that is the main subject-matter of psychology. Thus psychology is tied to *physiology*, because some of the organ-systems that physiologists study are associated directly with the behavior of the total organism. This is especially true of the sense organs, the nervous system, and the muscles; therefore the physiological principles that govern the activities of these organs are of great significance to psychology.

Anthropology and *sociology* are two of the behavioral sciences which link with psychology to form the other half of the picture. These sciences concern themselves with the behavior of people as entities in social life. They deal with man's behavior in *societies* and with the *culture* of such societies as an expression of behavior. They therefore call upon psychological knowledge regarding the behavior of man as an individual who reacts to and interacts with his fellows. In turn, psychology recognizes that the society in which an individual lives is an extremely important part of his total environment, and that it affects individual behavior in many ways.

Psychology has many significant relationships, too, with the *physical sciences*. Primarily, it often uses instruments and methods of measurement of the physical sciences in order to be able to specify what kinds of external events the individual is responding to (light waves, sound waves, etc.), and what form of reaction is being made (in terms of such variables as time, force, extent). There is, of course, no direct relationship between psychology and physical theory; no one supposes that behavior can be "explained" in terms of atoms or molecules. Nevertheless, the psychologist recognizes that his theories, along with those of various other scientists, must ultimately be compatible with those of physical science.

PSYCHOLOGY AS A SCIENCE

We need to examine in greater detail what is meant by psychology as a science. Fundamentally, psychology employs *an approach* and *a point of view* which is common to all sciences. It proceeds to investigate behavior by making *systematic observations*. These observations are "public," in the sense that they may be *repeated* by several different investigators, rather than being "private" to one. It employs *measurement;* that is, it attempts to put its observations into order along a scale. Finally, it seeks to *explain* the behavior that is observed, by relating it to *concepts* that are inferred from observations.

Behavior is then *predicted* on the basis of such concepts. When these predictions are compared to the behavior actually observed, a means is provided for revising and refining the concepts. Advances in psychology, as in other sciences, depend upon this process of objective verification and revision of concepts.

Observation

Psychology begins with *observations* of behavior, and the descriptions of these observations are the fundamental data of the science. The special instruments necessary to make these observations are relatively few in number, compared with those of many other sciences. Because of this, uninformed people sometimes draw the conclusion that psychology is nothing but "common sense," that is, common observation. But it is easy to show that common sense is in fact unsystematic, and that its conclusions are often very incomplete expressions of scientific facts.

Consider, for example, some well-known proverbs which attempt to summarize "common sense." Does "absence make the heart grow fonder," or is it "out of sight, out of mind"? There are certainly *some* conditions under which the first of these common-sense sayings will hold true, as there are some under which the second will apply. But the obviously conflicting implications of these proverbs show their limited usefulness as scientific generalizations. As a scientist, the psychologist might indeed be concerned with such variables as "fondness" and the state of being "out of mind." But he would be particularly concerned to make his observations systematic, so that he could specify which conditions lead to one and which to the other.

Measurement

A second part of the scientific approach in psychology is its concern with *measurement*, which means the systematic ordering of observations along a scale. For example, the behavioral scientist cannot be content to deal simply with the presence or absence of intelligence, or anger, or skill (just as the physicist cannot deal only with "pressure" or "no pressure"). He must devise some way of measuring amount of intelligence, degree of anger, and amount of skill. He therefore constructs a measurement scale for each of these behavioral functions. In this way he is able to put them into an order which may apply not only within the same organism, but also among different organisms. While it is true that scales of behavior seldom attain the elegance and precision found in scales of many physical variables, they nevertheless fulfill the basic purpose of measurement, which is the ordering of observations.

Causes of Behavior

Behavioral science, in common with other sciences, is concerned with discovering *causal relationships.* Psychology would be a very primitive science indeed if it consisted only in listed observations of behavior, whether or not these were ordered scales. Records of observations and measurements of behavior could fill many large volumes. But they would be of limited usefulness, even with an index. So psychology is concerned with finding the causes (that is, the antecedent conditions) of behavior. Suppose, for example, a man is found to be unable to distinguish certain "reds" from certain "greens." This type of behavior may be measured more precisely, and among a large sample of men, to provide us with an ordered set of observations about "color blindness." But the further question for science is: What are the causes of this behavior? The psychologist seeks to relate the observed phenomena to antecedent events in the man's immediate environment, in his past experience, and in his physiological functioning and organic structure.

Scientific Concepts

Psychology as a science seeks to *explain* the relationships it has discovered, by means of inferred *concepts* pertaining to "what must go on inside the organism." Such concepts are used to make a logical connection between antecedent events and the observed behavior. In a similar way, the concept of electrical resistance is used to explain the relationship between measured voltages at the two ends of a long thin wire. The *resistance* is not something that is directly seen; nevertheless it is used as a concept to provide a satisfactory explanation of the voltage drop. It has a strong reality because it can make rational sense out of a great many electrical measurements. In behavioral science, the concept of *learning* has a similar status. We may observe, for example, that skill at kicking a football has changed from a low to a high level, following some antecedent events which are commonly called "practice." (We shall be concerned with describing these events more precisely in a later chapter.) The concept of learning is used to account for these observations; this is the inferred process which explains the rise with practice in the skill of kicking a football. As a concept, learning derives its reality, not from this single set of observations, but from the fact that it can make sense out of many similar occurrences.

Since a science is best understood by means of its concepts, we shall have much to say about the concepts of psychology in this book. In fact, the next three chapters provide the basic framework of concepts which we will use throughout this book. These include the concepts of learning, memory, discrimination, skill, concept-using, and thinking.

AN EXAMPLE OF A PSYCHOLOGICAL INVESTIGATION

One of the difficulties faced by the scientific investigator of behavior is the fact that any given type of behavior, even the simplest form, often has multiple causes. There are usually several kinds of antecedent events, or *independent variables*, affecting a specific instance of behavior, and therefore several inferred concepts are needed to explain the relationships of all the variables to observed behavior. To illustrate this point, let us pretend that we have a serious investigator, with no knowledge of psychological concepts, who sets out to study a fairly simple form of behavior. We shall see how, beginning with some systematic observations and measurements, he proceeds to invent the kind of concepts he needs to account for the behavior he observes. Our investigator, we shall suppose, wants to find out how rapidly human beings can react to a signal. He supposes that this signal may be either a visual one, a light, or an auditory one, a tone. He sets up a panel containing a light which can be turned on instantaneously and provides a set of headphones through which a tone can be delivered to the ears. He then arranges an electrical circuit to energize a timer so that the latter will start the same instant a signal is presented, and be turned off when the individual being tested raises his finger from a telegraph key. Now he carries out the measurement of *reaction time*, using several individuals in succession, by simply saying he wants them to react as fast as possible by lifting the finger as soon as a signal is observed. He gives each individual two trials, on the first of which he presents either the tone or the light, and on the second the alternate signal.

The first regularity noted in the data obtained in this manner is this: the auditory signal, on the average, yields a faster reaction time than does the visual signal. In a number of individuals, our investigator finds that the average reaction time to the tone is 0.341 second, whereas when the light is presented, the average time is 0.379 second. Here is an important finding, which means that one significant variable affecting this simple form of behavior has been discovered. How fast can an individual react to a signal? The answer must be, it depends on the sense organ through which the signal is detected. The first concept which must be employed in explaining the behavior, then, is *differential sensory detection.*

Let us suppose that, having discovered this, our investigator proceeds to take additional measurements in the same individuals, for eight additional trials, using only the tone as a signal. When he does this, he finds the following average readings in seconds: 0.307, 0.292, 0.287, 0.279, 0.274, 0.270, 0.268. What is happening here? Starting with a reaction time of 0.341 second, our investigator finds a progressive shortening of the time to 0.268! With such data, how can he answer the basic question concerning how rapidly human beings can react to a signal?

It is evident that our investigator has uncovered another important concept for human behavior. This is the process of *learning*, which shows its effect in these data by the progressive improvement in performance throughout this set of measurements. The individuals are "getting used to the situation," or, more specifically, they are learning how to attend to the signal and how to lift their fingers most rapidly. Our investigator concludes, therefore, that in order to measure the rapidity of response to a signal, he must first take care of the learning process by giving a sufficient number of initial trials so that learning has been completed. At such a time, the performance will "level off," as indeed it is beginning to do in the data he has already collected.

Surely now, having teased out two important concepts, the investigator is ready to make his final measurements? Let us see. He now decides to run a more extended series of reaction-time measurements on the same individuals, so that they will progress past the point at which performance is affected by learning. He also decides to continue to use the tone as a signal, saying to his subjects, "Respond by lifting your finger as soon as you hear

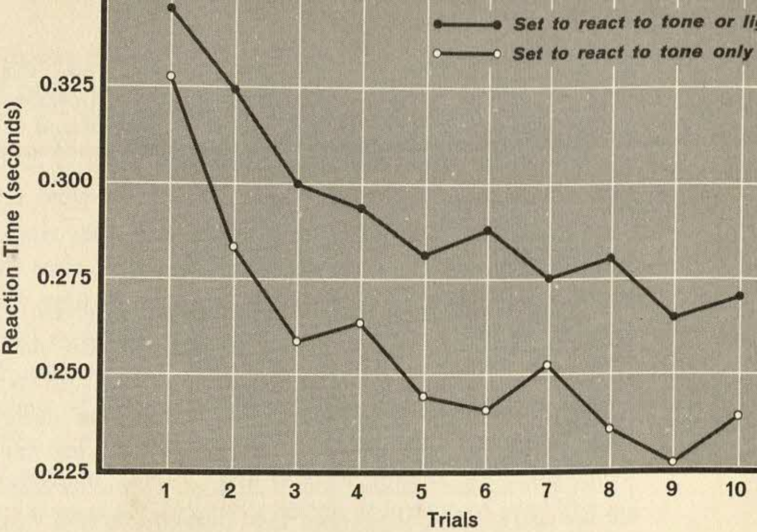

FIGURE 1.1. *Average reaction times of 39 individuals to a tone presented i successive trials. The two curves show the effects of set as well as learning. I the trials the subjects were told to expect only a tone (lower curve); in the half of the trials they were told to expect either a light or a tone. (Data Mowrer, O. H., Rayman, N. N., and Bliss, E. L.,* Preparatory set (expectancy *experimental demonstration of its "central" locus,* J. exp. Psychol., *1940, 26, 357*

the tone." Under these conditions, his next two average measurements are 0.227 and 0.224. Thus, suddenly, reaction times, which had seemed to be approaching a level of about 0.265, take a very significant dive! Again, he must ask himself, what has caused this state of affairs? He finds the answer in a slight change in his instructions. Whereas previously the individuals were told to react to a signal (tone or light), they now have been instructed specifically to respond to a tone. In the first set of conditions, they expected to have to respond *either* to a tone or light, whereas in the second, they expected only the tone. Here is a new concept, which the psychologist calls *set*. The individuals in the first condition have a *set* to respond to either tone or light; in the second condition, their *set* is to respond only to the tone.

Thus we see that the concepts with which the psychologist deals are inferred from his data. He may start out dealing with a perfectly straightforward situation in which he controls external events like a tone, and measures an objective physical variable like time. But he soon finds that the behavior he is studying is influenced and caused by multiple factors within the individual—processes like those of *sensory detection*, the *process of learning*, or the existence of a state of expectancy or *set*.

By this time, our investigator is no longer naive. His preliminary observations have enabled him to collect a set of data on human reaction time which will reveal in more exact form how such processes as learning and set affect human reaction time. If he began over again, he might collect the sort of data given in Figure 1.1, taken from an actual experimental study.[1]*

The figure shows the average reaction times of 39 human subjects to a tone. On half of the trials, these individuals were told to expect either a tone or a light as a signal; on the other half, they were set to expect only a tone. Notice that these results reveal in a very clear fashion the effects of *learning*, as shown by the progressive drop in time with increasing trials; and of *set*, as revealed by the differences between the two sets of points. If it were desired to find the answer to the question, how rapidly can an individual react to a tone, it would of course be necessary to give additional trials until the performance had completely settled down. But the investigator has already learned a good deal; he now knows the variables he will have to control to obtain a dependable answer to the question: How rapidly can a person react to a tone? And what is even more important, he has some notions about *what processes cause reaction time to change* from one situation to another.

THE POINT OF VIEW OF THIS BOOK

In this book we shall aim to convey an understanding of human behavior in terms of the concepts of psychology. In order to make these ideas most meaningful, we shall frequently describe typical experimental studies from which they are derived. The results of such studies will often be presented as graphs like Figure 1.1, in which the experimental or *independent* variable is plotted on the horizontal axis, the measured or *dependent* variable on the vertical axis.

We shall be primarily concerned with reporting the findings of psychological studies, rather than with describing how they were carried out. For the student who may be interested in learning about the methods and instruments of behavioral study, there are many sources available (see Reading References). Here we want to emphasize the content of behavioral science.

At the same time, there has of necessity been some selection of the material presented in this book, out of the great mass of data and theory which constitutes psychology. We have chosen to emphasize those aspects of psychology which pertain to the behavior displayed in *doing useful human work*. We want to consider how a human being responds to sights, sounds, odors, and pressures; how he learns and remembers actions, words, and skills; how he makes judgments and solves problems; and how he creates things and ideas. All of these activities are involved in man's work, as well as in his play.

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* Superscript numbers identify sources of data mentioned in the text, which are listed at the end of the book. These numbers are not employed when tables or figures identify the source.

Plan of the Book

We begin in Chapter 2 with an account of how the human being is put together, insofar as his *behavior system* is concerned. We see there that the major divisions of this system have the functions of *receiving* stimulation, *transmitting* signals, *acting*, and *energizing*, and we go on to describe the components of the human body involved in this behavior. In Chapter 3, we turn our attention to human functions of increasing complexity which require "higher loops" of the behavioral transmission-system. Here we introduce many basic concepts which will be used throughout the book.

In Chapter 4, we complete the picture of the behavior system with an account of the energizing system, or *motivation*. Again, we describe motivation's basis in physiological mechanisms, and progress to a consideration of the varieties of human motives.

Next, in Chapter 5, we consider the kinds of basic abilities that have been identified in man, and how they are measured. In Chapter 6, we describe how the process of learning can add to these basic abilities, and how it happens that a human being can acquire new and additional skills and knowledges and store them in his memory.

Following this, we are ready to deal with behavior in more detail, in terms of the functions identified in these early chapters. Chapters 7 through 10 describe the kinds of human capabilities which fall in the categories of discrimination, identification, motor and manual skills, concept-using and problem-solving, and social behavior.

In the next three chapters, 11 through 13, we see how this knowledge about human abilities is put to work in understanding and dealing with human beings. In connection with the performance of useful human work, we consider how jobs are described and how people are selected and trained for these jobs. Finally, Chapter 14 tells how our knowledge of human functioning may be applied to the problem of designing machines which human beings will operate.

SUMMARY

Psychology is the science of behavior. It aims to understand the behavior of organisms, by which is meant both the *prediction* of activities of the organism and the *specification* of antecedent events which cause various types of behavior.

Psychology is related to *biological science*, particularly physiology, from which it draws principles of organ-functioning. It is also related to the *behavioral sciences*, especially to anthropology and sociology, which are concerned with the behavior of people in societies and with the origin of cultures. From the physical sciences, psychology obtains a basic scientific approach, instruments and methods of measurement.

As a science, psychology uses *systematic observation* of behavior, which often differs from "common sense." It puts observations in order by arranging them on scales, which is another way of saying it employs *measurement*. Finally, it seeks to discover *causes* of behavior, by relating observations to inferred *concepts*. These pertain to events assumed to occur "inside the organism." Even in very simple forms of behavior, the investigator is almost at once faced with the necessity of inventing concepts to explain his systematic observations.

This book has the aim of conveying an understanding of human behavior, particularly the varieties of activities displayed in doing useful human work. It emphasizes the findings of scientific experiments on behavior, often expressed in the form of graphs.

READING REFERENCES

Andrews, T. G. (Ed.), *Methods of psychology*. New York: Wiley, 1948. This book contains descriptions of methods of psychological studies in various areas, written by experienced investigators.

Boring, E. G., *A history of experimental psychology* (2nd Ed.). New York: Appleton-Century-Crofts, 1950. A history of psychology, stressing its philosophical and physiological origins.

Pratt, C. C., *The logic of modern psychology*. New York: Macmillan, 1939. An account of the logical and theoretical foundations of psychology.

Wilson, J. T., *et al.*, *Current trends in psychology and the behavioral sciences*. Pittsburgh: Univ. of Pittsburgh Press, 1954. A set of lectures describing the relation of psychology to other behavioral sciences and to neurophysiology.

2

BASIC COMPONENTS OF BEHAVIOR

Here we begin our account of the human behavior system, which becomes the basic framework for your study of behavior. This system, like a machine system, can be viewed as being composed of subsystems which have the functions of input, transmission, output, and energizing. In order to understand how the system works, you will first need to learn its main components, which are described here. As a consequence, there is a good deal of detail in this chapter, and many unfamiliar terms.

Suppose you were shown a complicated machine which had been found on Mars, and were trying to understand what it was and how it worked. In all probability, you would first try to locate its major subsystems, those that performed input and output functions, as well as those concerned with internal transmission and with energizing. Then you would try to discover how the parts of each of these subsystems worked. Keep in mind that these are simply the basic components, whose existence and function you have to recognize if you are to understand how they function together to produce human behavior.

A human being is a complex thing. We know that this is true, not because of man's physical appearance or his chemical composition, but primarily because of the great range and variety of his behavior. Man can see, hear, and feel things; he can distinguish a tremendous number of fine differences in his environment; he can move, lift, and manipulate many kinds of objects; he can use a variety of symbols and languages in communicating with others; he can think, and he can solve complicated problems.

And because he can think, he can understand his own behavior. All

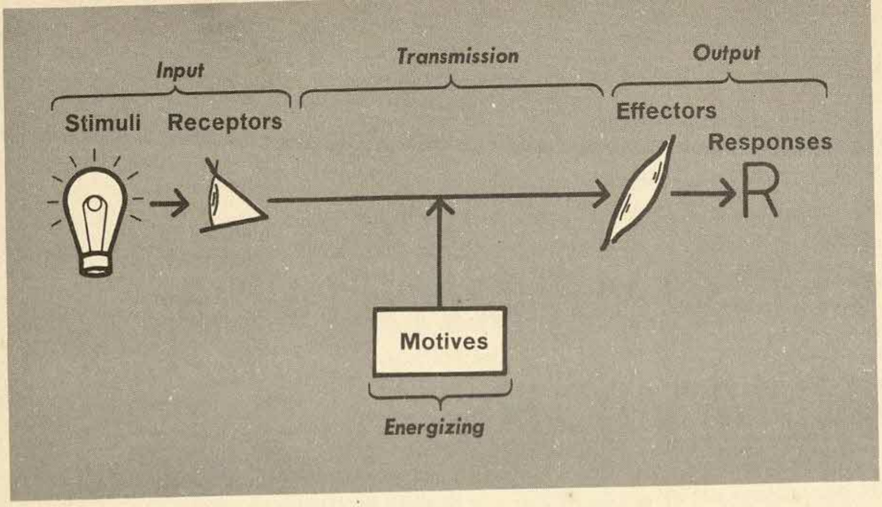


FIGURE 2.1. *The functions of the human behavior system.*

of us have some degree of understanding of human behavior, because we deal with it every day, both in ourselves and in other people. But a course in psychology should provide a more thorough and precise understanding of human behavior, and thus enable us to deal more effectively with it. We shall try in this book to give a framework for human behavior which makes possible its scientific understanding, and shows what we do know and what we do not know about it. Although there are areas which today can be described and understood only imperfectly, there is nothing mysterious about behavior.

As a first approximation to what behavior is like, we shall use a machine analogy, and think of man as housing within his frame a *behavior system.* Viewing man's behavior in terms of this kind of analogy will help to keep us from being overwhelmed by its complexity. Some behavior is complex, of course. But some is quite simple, and we can easily imagine a machine doing it. Furthermore, we need a common language to relate the behavior of man as directly as possible to the actual machines and tools he uses to perform useful work, from pencils to atomic reactors. Finally, the use of a machine or "system" analogy is a very common device in conveying understanding in all sciences. For example, the classical kinetic theory of gases is based upon a mechanical model describing the activity of molecules in an enclosed space. The theory of blood circulation is another example, in which the heart is conceived as a pump having an intricate set of valves that control the flow of fluid through the arteries and veins.

For these reasons, we shall adopt the analogy of a behavior system in attempting to provide a way of understanding human behavior. This is by no means the only way of viewing man's behavior. It is not the way, perhaps, of the physician, nor of the priest or the poet. But it is a way which seems particularly useful in conveying a scientific understanding of the kind of activities involved in performing useful human work.

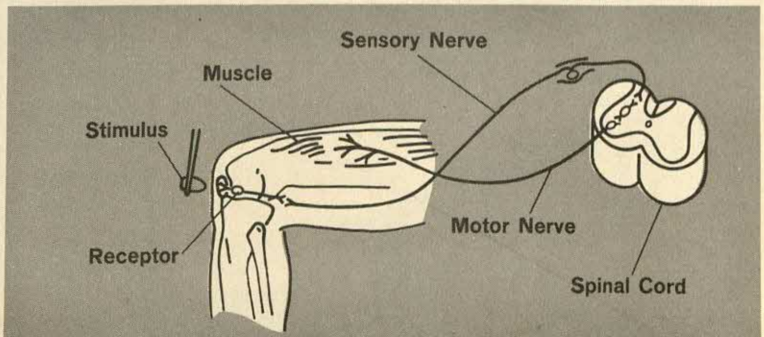
For our purposes, we conceive of the behavior system as having four basic functions. There is input, transmission, and output, as well as energizing, as illustrated in Figure 2.1. We shall deal in this chapter with the input and the output components, as well as with the transmission function in its most fundamental form. In the next chapter, we describe the various branches or "loops" in the transmission system, which are concerned in the more complex kinds of "data processing." In Chapter 4, we shall describe the energizing function in behavior—motivation. As we shall see there, energizing really displays many interactions with the transmission function, and is not simply a "power source."

BASIC COMPONENTS OF THE TRANSMISSION SYSTEM

At the simplest level of functioning, the input to the behavior system may be described in terms of energy from the environment called *stimuli*, which are detected by organs called *receptors* (represented in Figure 2.1 by an eye). After being coded, the information is transmitted along lines of the transmission subsystem to the *effectors* (represented by a muscle), which produce outputs called *responses*.

This simple form of functioning never actually occurs by itself in the intact human organism. Nevertheless, these basic events are what are conceived to occur in the *reflex arc*. An example of behavior which includes a reflex arc is the knee-jerk, illustrated in Figure 2.2. Physical energy from the environment, the *stimulus*, reaches the *receptor* or *sense-organ*, in this

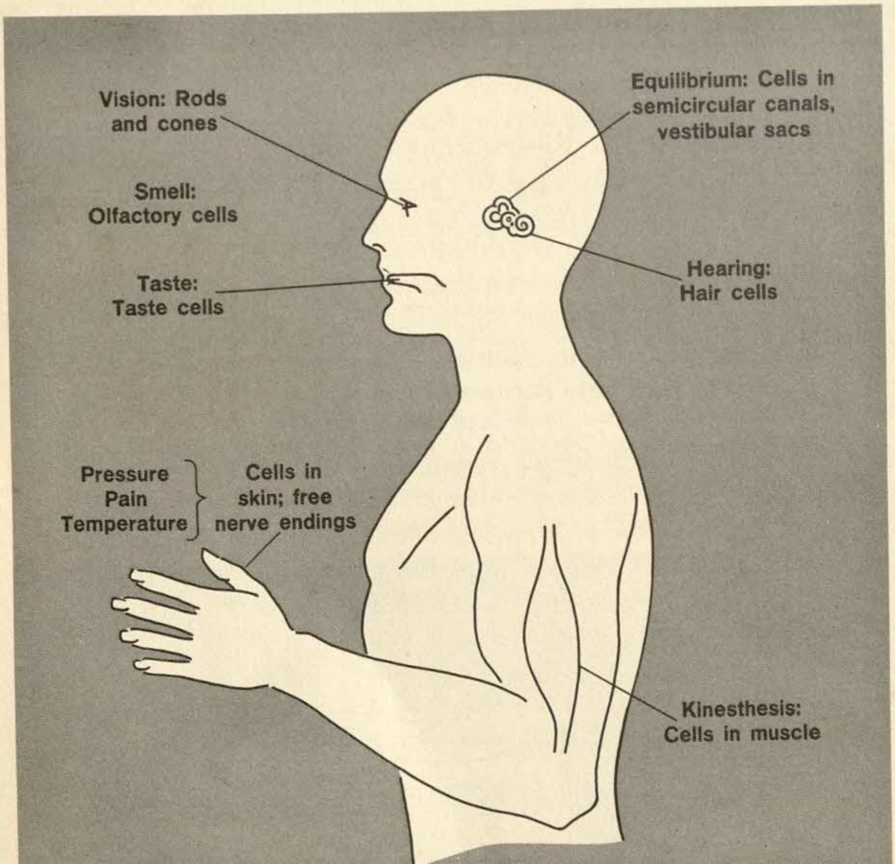
FIGURE 2.2. *The knee-jerk: a typical reflex arc. The rubber hammer delivers a blow to the knee which constitutes the* stimulus. *This arouses activity in* receptors *located in the patellar tendon. These in turn initiate a train of* nervous impulses *which travel over* sensory nerves *to the spinal cord. Central connections are made at this point with* motor nerves, *which carry nervous impulses to* effectors, *in this case muscles in the leg, which contract to raise the leg. (Adapted from Dashiell, J. F.,* Fundamentals of general psychology *(3rd Ed.). Boston: Houghton Mifflin, 1949)*



case located in the patellar tendon in the region of the knee. The energy is transformed by the receptor into *nervous impulses,* which are carried by *sensory nerves* to a central connection point in the spinal cord. Here a connection is made with *motor nerves,* which carry the signal to a set of *effectors* or muscles in the leg. The muscles transform these signals into movement which is seen by an external observer as a jerk of the leg.

Although the primary event which takes place in this example may be described and understood in terms of the reflex arc, it is easy to see that this is too simple a concept for the behavior as a whole. Three things make this immediately obvious. One is the fact that the human being is aware that his patellar tendon has been struck. The second is that he is aware that his leg moves. And still a third is the fact that he can deliberately tighten the muscles of his leg in such a way as to alter (although he cannot entirely prevent) the occurrence of the knee-jerk. All of these things show that transmission of nervous impulses, even in the simplest behavior, takes

FIGURE 2.3. *Location of receptors. This drawing shows the position of the mechanisms that provide inputs to the human nervous system. The specialized receptors for vision, hearing, smell, taste, and equilibrium are localized in small areas within the head; those for pressure, pain, temperature, and kinesthesis are distributed widely throughout the body (in the skin and muscles).*


Vision: Rods and cones
Equilibrium: Cells in semicircular canals, vestibular sacs
Smell: Olfactory cells
Taste: Taste cells
Hearing: Hair cells
Pressure
Pain
Temperature
Cells in skin; free nerve endings
Kinesthesis: Cells in muscle

place within several different loops of the nervous system. We shall consider this point more fully in a later portion of this chapter when we discuss nerve pathways.

Before we do, however, we must describe the *parts* of this simple transmission system; namely, the *receptors*, whose function is detection; the *effectors*, which produce action; and the transmission line connecting them, which consists of *nerves and their connections*. The human individual has many reflex arcs. He reacts to a number of kinds of stimuli with a number of different receptors, using several types of effectors. What and where are all these parts?

RECEPTORS

Let us consider first the detecting end of the transmission system, the receptors, and the stimuli to which they are sensitive. The number of types of receptors (senses) there are depends on how one classifies them. In any case, there are more than the classical five; the most usual modern classification yields nine. These are vision, hearing, smell, taste, touch, temperature, pain, kinesthesis (the muscle sense), and equilibrium. Here we shall describe what they are, where they are located, and the nature of their sensitivity to stimuli.

Vision

The human eye is shown in cross section in Figure 2.4. Light waves enter through the transparent cornea, and pass through the lens, which focuses them on the sensitive surface called the *retina*. This surface is composed of sensitive cells, the visual receptors, called *rods* and *cones* (because of their shapes). Within these cells there takes place a process which transforms light energy into nervous impulses. Basically, this is a photochemical process similar to that which occurs on a photographic film. The nervous impulses which are generated here pass out of the eye by way of the *optic nerve*.

The human eye is sensitive to light waves ranging approximately between 400 (violet) and 800 (red) millimicrons in length (16 millionths to 32 millionths of an inch). Light visible to humans is a very small part of the electromagnetic spectrum, which extends from the extremely short cosmic rays at one end to the very long radio waves at the other. The energy region composed of wave lengths just shorter than those of the visible spectrum is called ultra-violet, and those wave lengths which are barely longer, infra-red.

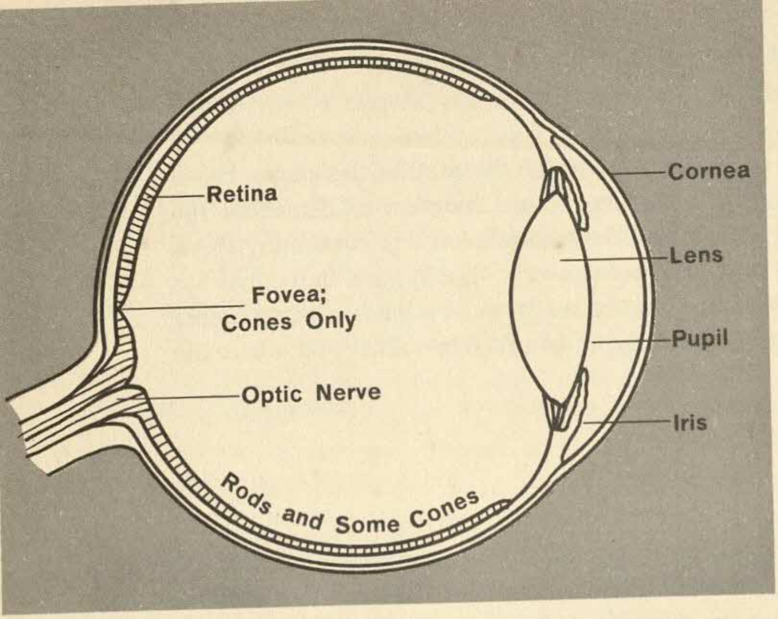


FIGURE 2.4. *Cross section of the human eye.*

The lens of the eye is elastic, and its shape is controlled by attached muscles. Accordingly, the lens flattens and increases its focal length when distant objects are observed, thus focusing the pattern of light waves on the retina. When near-by objects are brought into focus, the lens is thickened and its focal length decreased by contraction of the surrounding muscles.

Focusing is also accomplished by movement of the entire eye in its socket, or by moving the head itself. These actions direct the light waves to the central part of the retina, called the *fovea,* which contains only *cones.* It is known that this region of the retina is active in the clearest vision, and in color vision. On the other hand, the *rods,* which occur only outside the fovea, are more sensitive in the sense that they react to smaller quantities of light. They are active when we see in the dark, whereas the cones are not.

Hearing

Sound is generated by vibrating bodies and travels as wave motion of a medium, usually the air. As shown in Figure 2.5, sound waves enter the *auditory canal,* which is a tube about one inch long and one-quarter inch in diameter. These waves set in motion the eardrum, at the entrance to the middle ear. From this point the vibrations are transmitted primarily by means of a lever system formed by three tiny bones, descriptively called the hammer, anvil, and stirrup. The last of these is attached to a membrane

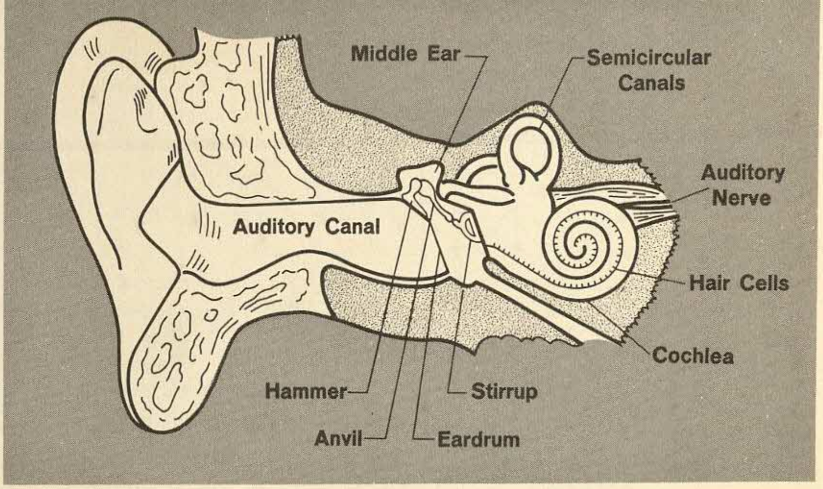


FIGURE 2.5. *Cross section of the human ear.*

of the *cochlea* called the *oval window.* The vibrations of this membrane set in motion a fluid within the cochlea, which stimulates the *hair cells* that lie along a membrane which stretches between the walls of this spiral-shaped organ. These *hair cells,* so-called because of their shape, are the receptors for hearing. It is generally believed that they are stimulated mechanically by the motion of the cochlear fluid.

The mechanical waves which can stimulate the human ear range in frequency from 20 to about 20,000 cycles per second. It is a well-known fact that many animals are sensitive to higher frequencies of sound. Dog whistles that produce frequencies above 20,000 cycles are inaudible to man, but are reacted to promptly by a properly trained dog. It is common for older people to begin to lose sensitivity to sounds at the higher end of the audible range.

Smell

The receptors for smell are *olfactory cells* which are actually nerve fiber terminations, located in the uppermost part of the nasal cavity. Most of the air breathed through the nose goes directly through lower passages of this cavity to the pharynx and lungs. The olfactory cells are stimulated by gases which reach them by convection and diffusion. Sniffing, however, generates within the nasal passages swirls of air which then carry odorous particles to the highest region of the cavity, where the smell receptors are more strongly stimulated than they are as the result of normal breathing.

Although it is possible to name many examples of gaseous substances which are smelled, the physical nature of the energy that constitutes the

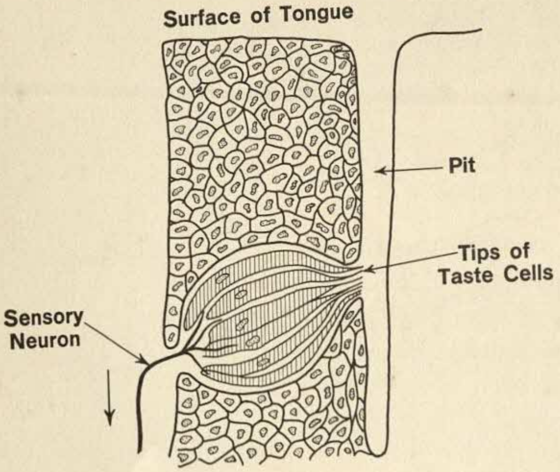


FIGURE 2.6. *A taste bud, composed of a number of taste cells. The tips of these cells come into direct contact with solutions. (From Woodworth, R. S.,* Psychology *(4th Ed.). New York: Holt, 1940)*

stimulus for smell is not known. Perhaps it will turn out to be some property of the molecular structure of gases.

Taste

The receptors for taste are *taste cells* which are arranged in groups called *taste buds,* located in the tongue and parts of the throat. A taste bud is shown in Figure 2.6. These receptors are stimulated by certain liquid chemical solutions. As in the case of smell, the exact nature of the stimulating energy is unknown, but is thought to be some property of molecular structure. Taste stimulation appears, however, to divide itself into four basic distinguishable categories. These are sweet (typical stimulus: sugar), salt (sodium chloride), sour (hydrochloric acid), and bitter (quinine). Furthermore, parts of the tongue are differentially sensitive to these four kinds of substances. The tip is most sensitive to sweet, the tip and sides to salt, the sides to sour, and the back to bitter. It may be that there are actually four different kinds of taste receptors, although these have not been definitely identified.

The tasting of any particular liquid may involve several sets of receptors. For example, taking a mouthful of hot coffee may result in the stimulation of smell receptors from the aroma, as well as of both sweet and bitter taste receptors. In addition, the tongue and mouth are supplied with temperature receptors (to be described below), and these are also stimulated. The total complex of stimulation which makes up the taste of hot coffee is therefore not necessarily a simple thing. Many "taste" discriminations of common foods are dependent upon differences in the kind of stimulation provided to other sense organs, particularly those of smell.

Skin Receptors

The skin is sensitive to three major classes of stimulation, usually referred to as pressure (touch), temperature, and noxious stimuli (pain). Sensitivity to these classes of stimuli varies widely over the surface of the skin. For example there are relatively many spots on the fingertips which are sensitive to pressure, but relatively few on the back. Similarly, the cheek has many more spots sensitive to temperature than does the surface of the arm or leg. The fact that these types of stimuli are experienced differently would seem to imply the existence of three different types of receptors. However, although this matter has been extensively studied, no such classes of receptors have been definitely identified. It is known that the skin is richly supplied with free nerve endings, and that these sometimes occur in elaborated form enclosed in various capsules which differ in their structural appearance. The basic type of receptor for all skin stimulation may be a nerve ending.[1]

Touch occurs when the surface of the skin is deformed by pressure. The stimulus is a gradient of pressure between two adjacent skin regions. Thus, if one dips a finger into a jar of mercury, touch is experienced only at the ring where mercury ends and air begins, not over the entire immersed surface of the finger.

Warm is experienced when the stimulation is between the range of about 32.5°C to 40°C. From 40°C to 46°C the experience is reported as "hot"; and above 46°C, "burning hot" is reported, presumably because the pain receptors are stimulated.

Cold is reported as a result of stimulation between about 12.5° and 32.5°C. Below 12.5°, "burning cold" is usually reported, again because of the involvement of pain receptors.

Pain is produced by noxious or injurious stimulation, particularly to free nerve endings. This stimulation may be mechanical (as a sharp point), chemical (as an acid injected into the skin), thermal (accompanying extreme heat or cold stimulation), or electrical.

Kinesthesis

An extremely important source of stimulation originates in the movement of parts of the body by muscles, and is called *kinesthesis* or the *kinesthetic sense.* Receptors sensitive to this type of "internal" pressure are located in the muscles, in tendons, and on the surfaces of joints. This is the source of stimulation which makes the human individual aware of the jerk of his leg (even if he isn't looking), after it has reacted initially to the blow on the knee. This kind of sensitivity forms the basis of one of the most important and widespread feedback systems of the human body. This enables the individual to touch designated parts of his body or limbs with his eyes closed, or to perform various other "positioning" activities without looking. Rhythmical movements also depend upon this type of sensitivity for their performance. The stimulus for one tap of the foot in "beating time," for example, arises partly from the immediately preceding movement through the stimulation of kinesthetic receptors in the muscles of the foot and leg.

The Equilibrium Sense

We have already spoken of the ear in connection with hearing. Another part of the inner ear is concerned with an entirely different kind of internal sensitivity, sometimes called the *static sense,* or the *sense of equilibrium.* One stimulus for this sense is accelerated motion of the head in any direction. This motion is reflected in the motion of fluid within one or more of three *semicircular canals,* each of which is aligned to one of the three spatial planes, forming a three-dimensional coordinate system. The location of these canals in the inner ear is shown in Figure 2.5. The accelerated motion of the fluid in each canal stimulates receptor cells located along its walls. Similar kinds of receptors located in inner-ear structures known as *vestibular sacs* are believed to be responsive to continuous motion in one direction (as opposed to acceleration), as well as to gravity.

EFFECTORS

We have now finished our brief review of the detecting part of the transmission system which constitutes the basic mechanism of human behavior. Now let us look at the other end: at the structures which transform neural impulses into responses.

The effectors are *muscles* and *glands.* Nervous impulses arriving over motor nerves end in terminal junctions within these effector organs. In muscles, this signal is transformed into a *contraction* or *relaxation* of tissues, resulting in movement of the muscles and the structures attached to them. In glands, the nervous impulse sets off *secretion* of some fluid, either on the surface of the body or internally.

Muscles

Muscles are generally described in three categories distinguished by their physiological properties as well as by their location within the human

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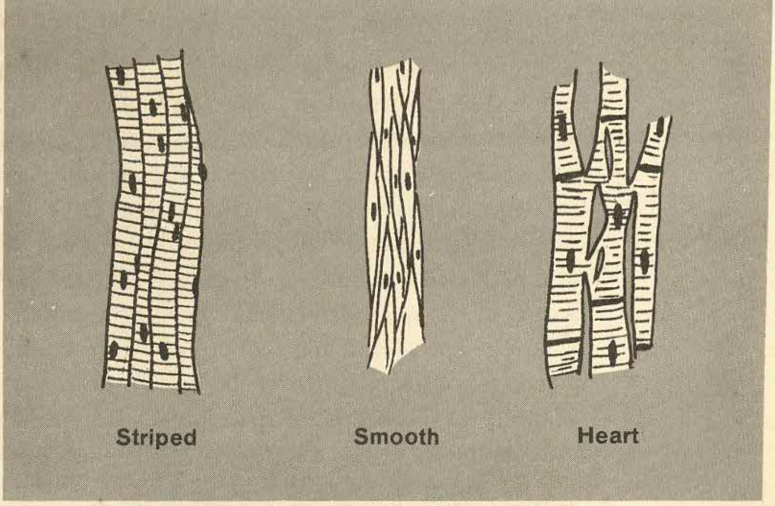

FIGURE 2.7. *The three types of muscles.*

body. These are the *striped* muscles, the *smooth* muscles, and the *heart* muscles.

The *striped muscles* are the ones which move the body and its limbs. There are over six hundred of these, distributed throughout the body. Generally speaking, they operate by exerting a force upon levers which are provided by the bony skeleton. They are particularly characterized by a response to neural signals which is more rapid than that of the other types of muscles. *Smooth muscles* occur in the visceral organs of the body, such as the stomach, intestine, and blood vessels. Their characteristic response is slow and rhythmic. *Heart muscles* are distinguished from the other two types by their appearance and internal organization. They display an intermediate speed of contraction, and strong rhythmic responses. Figure 2.7 shows the structure of the three kinds of muscles.

OUTPUT CHARACTERISTICS OF MUSCLES. From an anatomical point of view, it would be possible to measure the response characteristics of individual muscles. However, in line with our consideration of effectors as the output elements of a transmission system, a more useful point of view is to look at the effects of muscular action in terms of the movement of the trunk and limbs of the body. The movement of a body member, such as the jerk of the leg in the knee-jerk reflex, is produced by the integrated action of muscle groups, not by any single muscle. In fact, we know from other evidence that in order for the muscle groups on the upper side of the knee to raise the leg by *contraction*, an antagonistic set of muscles on the under side must simultaneously react to neural impulses signaling *relaxation*. This is simply another example indicating that there are other "loops" in the simple transmission system with which we are dealing.

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From the viewpoint of output, the action of trunk, limbs, and appendages can be described in terms of the characteristics of *speed* and *force* of response of skeletal muscles. Reaction-time measures of *reflexes,* which include the time taken by receptor action and neural conduction as well as muscular contraction, have been made on a number of human reflexes. Generally, these times are of the order of .03 to .07 second.[2] (This may be contrasted with values for voluntary reaction time, involving higher level "loops" of the nervous system, which are generally in the range of .15 to .25 second.) Speed and force of muscular reactions are usually measured in connection with certain specific human activities; no comprehensive list is presently in existence. For example, the speed and force of braking an automobile, or of the airplane pilot's pull on a stick, are important factors in the design of specific human jobs involving man's interaction with a machine. In certain kinds of activities, other characteristics of muscular responses become of considerable importance. For example, the characteristic of *precision* may be important in an activity like watchmaking; *smoothness* and *steadiness* of muscular movement in aiming a gun at a moving target. We shall describe these in more detail in a subsequent chapter.

Glands

The glands are specialized organs which are stimulated by nervous impulses to manufacture some chemical product which plays a part in body functioning. Those that discharge their product through some opening or duct are called *duct* glands; those that secrete their product into the blood stream are called *endocrine* or *ductless* glands.

The *duct* glands include the *salivary* glands in the mouth, the *liver,* the *pancreas,* and others located in the walls of the stomach and intestines. All of these play a part in the digestion of food. Certain of the duct glands excrete their products to the outside of the body. These are the *tear* glands, the *sweat* glands, the *kidneys,* and the *sex* glands (ovaries in the female and testes in the male).

The *endocrine* glands secrete a variety of chemical products known as *hormones,* whose effects are many and marvelous. Some hormones appear to have primarily a *regulatory* function on physiological processes. For example, the *Islands of Langerhans* in the pancreas secrete a hormone called *insulin* which regulates the sugar consumption of the body; the adrenal cortex secretes a hormone which regulates salt balance. Other hormones have a *growth-controlling* function, as is true of the products of the pituitary gland, the thyroid gland, and the sex glands. Finally, some hormones have an *energizing* function, like the hormones which arouse sexual activity, and *adrenin,* a product of the adrenal glands which acts through the blood

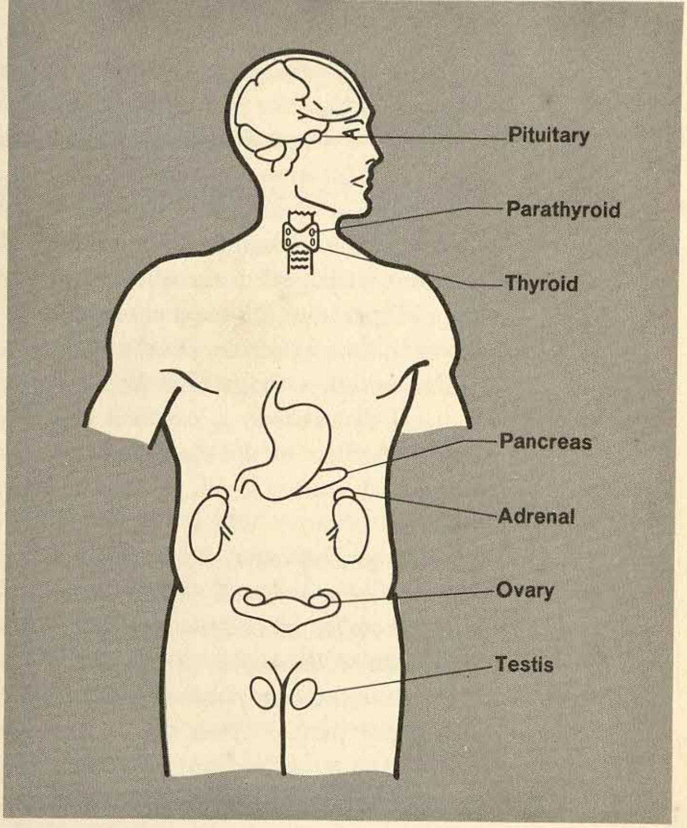


FIGURE 2.8. *Location of the major* endocrine glands.

stream to produce the heightened activity and keyed-up emotional state which accompanies an "emergency" reaction of the human being. The locations of the major endocrine glands in the body are shown in Figure 2.8.

One of the most important facts about the endocrine glands is that their effects interact with each other. Besides secreting products whose direct effects on bodily functioning are fairly clear, the activity of certain endocrine glands is known to affect the activity of others. The total picture of endocrine functioning has by no means emerged yet, despite the continuing efforts of many capable investigators.

THE CONNECTING SYSTEM: NERVE PATHWAYS

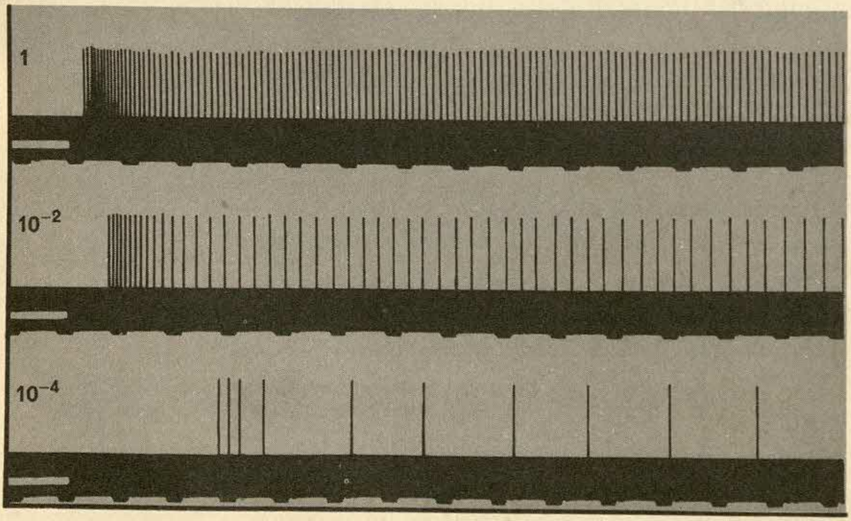
Having looked at the receptors and effectors, the two ends of our transmission system, we are now ready to return to the central portion, the nerve pathways. First of all we shall examine some of the properties of this conduction system in its simplest form as it is conceived to exist in the reflex arc. In the next chapter, we shall examine some of the varieties of higher "loops" in this conduction system which give it great complexity and tremendous capacity.

Some Basic Facts of Nervous Conduction

A nerve is a bundle of individual fibers called neurons. The neural impulse is a cyclical disturbance of the electrical potential between the outside and inside of the outer membrane of the neuron. This disturbance or impulse passes along the neuron, at a rate varying with the diameter of the neuron, within a range of 3 to 300 feet per second. The strength of this electrical disturbance is constant in a given neuron in a normal environment, regardless of the strength of the receptor process (or direct stimulation) which started it off. A neuron is thus said to exhibit an "all-or-none" response.

Neurons, however, differ widely in the strength of stimulation necessary to make them respond. In physiological studies, the lowest strength of direct electrical stimulation to which a given neuron will respond is called its *excitation threshold*. Following its initial response, each neuron also exhibits a *refractory phase* of a few thousandths of a second, during which no impulse passes. After this, it is ready to respond again in its "all-or-none" fashion. When amplified and displayed on an oscilloscope, these impulses appear as a regular series of spikes. Records of the responses of a single neuron of an optic nerve to three different stimulus intensities are shown in Figure 2.9. As can be seen, increased intensity of stimulation results in a greater frequency of impulses, without changing their strength.

FIGURE 2.9. *Neural impulses in a single neuron of the optic nerve of the Limulus crab, in response to steady light stimulation. These records were obtained with light intensities varying in the ratios of 10,000: 100: 1. The rectangular depressions at the bottom of each record mark off intervals of .20 second. (From Hartline, H. K., The nerve messages in the fibers of the visual pathway,* J. opt. Soc. Amer., *1940,* 30, 239-247)



A nerve exhibits activity which is the sum of the activity of its individual neurons. The amount of neural activity in a nerve may be readily measured by well-known electrical measurement techniques. The response of a whole nerve is continuous, and not in discrete steps like that of the neurons which make it up. This is because each individual neuron is firing at a different rate, since each has a different conduction rate and refractory period. Furthermore, increasing the intensity of stimulation results in a direct increase in the total nervous response in the whole nerve. The reason for this is that each individual neuron has a different excitation threshold, and increasing stimulation simply brings more of them into play.

The Brain and Spinal Cord

As we have already indicated, the simplest kind of conduction in a reflex arc involves a sensory nerve, a set of connecting fibers, and a motor nerve. There is no direct physical connection between these three stages of neural conduction. Instead, between each set of nerve fibers there is a junction point called a *synapse,* and the neural activity must bridge each of these very fine gaps. Somehow, the nervous impulse of one neuron ending at a synapse generates a new impulse in the next neuron which begins there. Thus, while the whole train of events from receptor to effector is continuous, it is made up of several successive physiological processes.

In general, tremendous numbers of connecting neurons and synapses between them are located in the central part of the nervous system, the *spinal cord* and *brain.* The first reason why things begin to get a little complicated in this region is the fact that neurons make many synaptic interconnections with other neurons. Even in the simple reflex arc, there are many individual synaptic pathways over which a signal can travel from receptor to effector. Because of the existence of this multiplicity of connections, the central nervous system also has some other properties which are important in human behavior. Particularly, there is *facilitation,* by means of which impulses arriving simultaneously from another source may make synaptic connections that increase the strength of ongoing neural activity in a motor nerve and thus increase the size of the muscular response. The knee-jerk, for example, is increased in strength when at the time the knee is struck the individual is occupied in squeezing his hand into a tight fist. Other sorts of neural activity may cause *inhibition,* or a decreased strength of neural impulse, resulting from a kind of interference effect at the synapse.

Besides providing rich interconnections of sensory and motor neurons, the spinal cord contains ascending and descending neural pathways which serve to connect incoming and outgoing signals with higher and more complex neural activities. There are many such higher loops in the central nervous system. Some of these have circumscribed locations or "centers" which are known to be active in the automatic regulation of behavior, as in breathing and the maintenance of posture and balance. Others are centers for emotional behavior, and some of the most interesting appear to be centers controlling motivation, the energizing function which we shall describe in Chapter 4. Among the most important higher loops are those located in the large mass of convoluted nervous tissue that lies on top, called the *cerebral cortex.*

A basic idea of the process involved in such higher level loops is illustrated in Figure 2.10. Superimposed upon the reflex arc is a higher level connection to and from the cortex.

Sensory neurons which carry impulses up the spinal cord to the brain eventually reach an area called the *sensory-projection area,* located as shown in Figure 2.11. Synaptic connections are made here with various

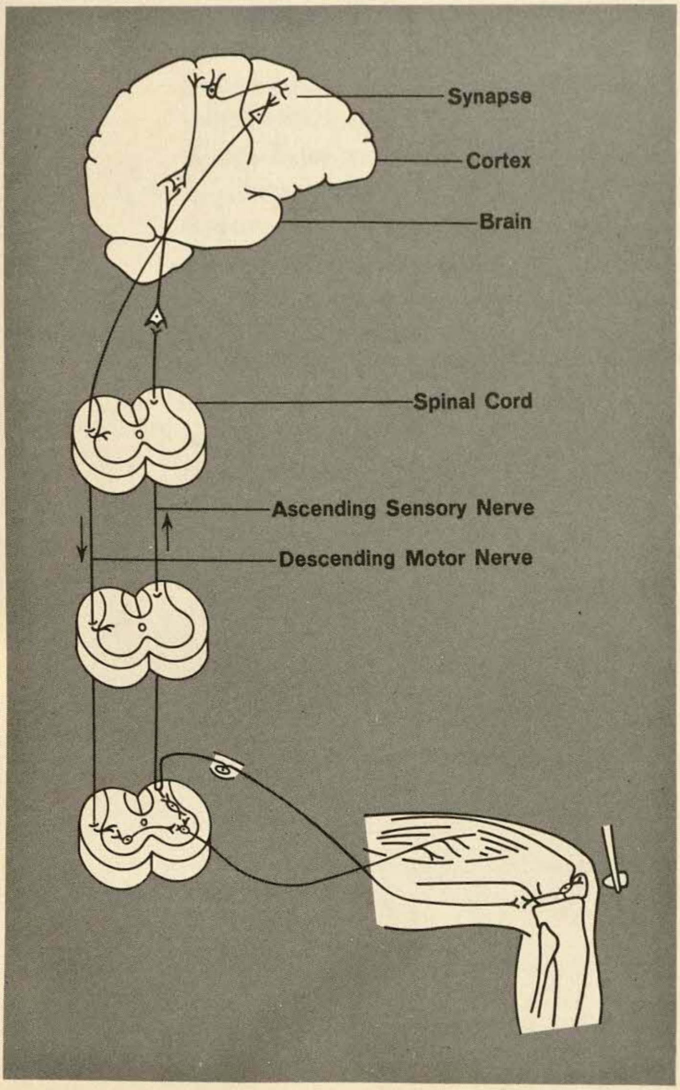


FIGURE 2.10. *Some higher level connections associated with the knee-jerk. Besides the basic reflex arc pictured in Figure 2.2, ascending sensory nerves carry impulses to the cortex of the brain. Also, nerve impulses originating in other parts of the cortex are carried over descending motor nerves and finally stimulate muscles of the leg. (Adapted from Dashiell, J. F.,* Fundamentals of general psychology *(3rd Ed.). Boston: Houghton Mifflin, 1949)*

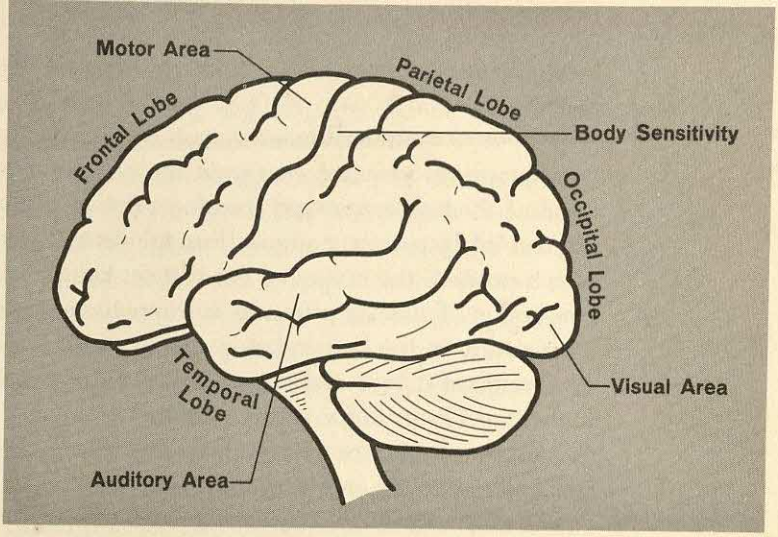


FIGURE 2.11. *Sensory- and motor-projection areas in the cortex.*

other parts of the cortex. At this point the individual becomes aware that his knee has been tapped. Let us suppose he then decides to hold his knee stiff, so that his leg will not jerk upwards. We know, of course, that he will not be successful, primarily because the impulses in the basic transmission system are already well on their way to the muscles which raise the leg. He may, however, be quick enough to shorten the course of the kick by bringing other muscles into play to hold the leg stiff. Such signals begin in a *motor-projection area*, whose location is shown in Figure 2.11, and transmitted by tracts of neurons down to the spinal cord. These impulses pass through synapses to motor nerves, and thus provide the signals which contract the sets of muscles that hold the leg stiff and reduce the extent of the knee-jerk.

Now, this is the basic pattern of the nervous system: a transmission system with a detector (receptor), a connecting line (nerve) with numerous branches and couplings (synapses), a reactor (effector); and superimposed upon this, a tremendously complex system of parallel and feedback loops (the brain). It is important to remember this basic pattern of organization, and to recognize that any behavioral sequence can be analyzed in this way. It is even more important to realize that the variety and complexity of human behavior depends upon the existence of the complex neural loops in the human brain.

SUMMARY

Human behavior may be viewed scientifically as the product of a *behavior system* having the functions of input, transmission, output, and energizing.

Input to the transmission system is described in terms of *stimuli,* which are changes in physical energy in the environment that are picked up by organs called *receptors* and transformed into *nervous impulses.* The latter are carried by *nerves,* and pass through central connections to the *effectors,* which produce the output of the system, known as *responses.* The simplest conception of this set of events is the *reflex arc,* which never occurs in this simple form in the human being. An example is the *knee-jerk reflex,* which is accompanied by a number of behavioral events that reflect the action of higher level loops in the nervous system.

The reception of stimuli falls into the categories of vision, hearing, smell, taste, touch, temperature (warm and cold), pain, kinesthesis, and equilibrium. Each of these senses is stimulated by a specific form of physical energy. In some cases, as in hearing, the type of energy involved is well known; in other cases, as in smell, it can only be specified in a general way. The *receptors* or *sense cells* have been specifically identified for most senses, but remain somewhat in doubt for others (for example, touch).

Concerning output, the *effectors* are of two basic types, *muscles* and *glands.* Muscles may be *striped,* concerned with moving the body and its limbs; *smooth,* occurring in the visceral organs; or *heart muscles,* which have a different structure from the other two classes. These types of muscles differ in their speed and in the rhythmic nature of their contraction. The action of trunk, limbs, and appendages can be described as output in terms of *speed* and *force* of movement, as well as *precision, smoothness,* and *steadiness.*

The glands are of two types: *duct glands,* which discharge their chemical products through ducts; and *ductless* or *endocrine* glands, which secrete products into the blood stream. The chemical substances manufactured by the latter are called hormones, and affect physiological functioning in various ways which sometimes have marked effects on behavior.

The connecting system for inputs and outputs is composed of bundles of individual *neurons* called *nerves.* The *nervous impulse* is a cyclical electrical disturbance which travels along the outer membrane of the neuron at a rate of between 3 and 300 feet per second. Each neuron fires in an "all-or-none" fashion, but the response of a whole nerve is continuously varying in intensity.

The simplest kind of nervous conduction, occurring in a reflex arc, involves a *sensory nerve,* a set of connecting nerve fibers, and a *motor nerve.* Between each of these are junction points called *synapses.* A large number of connecting neurons and synapses between them are located in the *central nervous system,* composed of the *spinal cord* and the *brain.* The spinal cord also contains ascending (sensory) and descending (motor) neurons which serve to connect incoming and outgoing signals with higher levels of the brain.

There are many higher loops in the brain, some of which have specific locations and function as centers for the regulation of automatic behavioral functions like breathing. Some important nerve tracts ascend the cord to reach the highest portion of the brain, the *cerebral cortex,* where they terminate in a *sensory-projection area.* Many additional connecting fibers and synapses are found in the cortex. There is also a *motor-projection area,* the starting point for nervous impulses that travel down the spinal cord and out to the muscles.

The basic pattern of the nervous system is that of a transmission system. Stimuli are detected by a receptor and transformed into nervous impulses which travel over sensory nerves, through synapses, to motor nerves and to an effector. Along this route there is a great variety of complex interconnections at various levels in the nervous system, up to and including the cortex.

READING REFERENCES

Gardner, E., *Fundamentals of neurology* (Rev. Ed.). Philadelphia: Saunders, 1952. An introductory text on the nervous system and its functioning.

Geldard, F. A., *The human senses.* New York: Wiley, 1953. A comprehensive account of basic knowledge about the senses.

Morgan, C. T., and Stellar, E., *Physiological psychology* (2nd Ed.). New York: McGraw-Hill, 1950. A textbook which deals with relations between physiological variables and behavior.

Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954. A basic text in experimental psychology.

3

FUNCTIONS OF THE BEHAVIOR SYSTEM

Now that we have seen how an input signal gets into the behavior system, and gets transformed into responses, we take up the more complex kinds of transformations that may occur. There are a number of kinds of transformations, all of them dependent on the existence of different channels or "loops" in the transmission system (the nervous system). These transmission loops determine the classes of human behavior which can be identified in the great variety of activities performed by human beings. In addition, we describe here a very basic and important property of the nervous system, the acquiring and storing of new patterns of connections—that is, learning and memory.

The types of human behavior functions you encounter here will be easy to relate to your everyday experience; you will readily see that these are the kinds of things you and other human beings do all the time. At the same time, you should realize that we shall meet these kinds of human behavior again and again throughout this book; in fact, it is these categories of behavior that the book is all about.

What the psychologist is primarily trying to understand is the functioning of the human behavior system. In this effort, the psychologist is in a position opposite to that of the engineer who must design a machine to function in certain ways. The engineer begins with a statement of the "machine behavior" he wants to achieve. For example, he knows he must try to design a radar set with a specified range, accuracy, and sensitivity. What he attempts to develop is a system of interconnecting parts which will perform these functions.

In contrast, the psychologist has before him a completed complex human being, who can function in certain observable ways. First, the psychologist must describe and catalogue these functions. Then he has before him the even more formidable task of making sense out of the interconnecting parts which can produce such functions. In other words, he tries to infer what kinds of parts and connections *must be there,* in order that the behavior he observes could possibly take place.

As we have said in the previous chapter, the basic parts of the behavior system are sense organs, the connecting nerves, muscles, and glands. In a fundamental sense, behavior begins with a physical stimulus and terminates with a response. The neural pathways and mechanisms involved in this sort of automatic transmission are fairly well known and understood. We understand less about the functioning of higher-level loops, or the synaptic networks to which they are connected in the cerebral cortex. We do know that there must be certain kinds of mechanisms, which must have certain properties in order for them to make possible the types of behavior we observe in human beings.

What kinds of things does a human being do, besides react to stimuli, that tell us the nature of his behavior system?

DISCRIMINATION

One kind of behavior exhibited almost continuously by the human individual is *discrimination.* This is a basic function of the input mechanisms of the behavior system, depending for its occurrence on characteristics of receptors, sensory nerves, and their central neural connections. The individual reacts differentially to stimuli. In other words, his behavior indicates in some manner that he can "tell the difference" between two stimuli which are physically different.

Discrimination of stimuli is indicated when an individual responds in a different way to different stimuli. A human being's behavior evidences discrimination, for example, when he presses his automobile brake or accelerator in response to the red light or the green light of a traffic signal. He discriminates when he says one note of a piano sounds higher than another. Likewise, he discriminates when he reacts differentially to two different amounts of pressure on his skin, or to two different degrees of cold and warmth. Human capabilities for discrimination within each of the senses have been measured extensively and with considerable accuracy. (For more detail, see Chapter 7.)

Within any one sense department, it is apparent that human beings can discriminate different aspects or "dimensions" of physical stimulation. For example, in the case of vision, individuals can react differentially to two lights of different intensity (brighter or dimmer); of different wave length (color); and of different wave composition (the color may be more or less "pure" or "saturated"). Likewise, in hearing, the individual can discriminate differences in intensity (loudness) and wave length (pitch). Sometimes, the physical differences that can be discriminated are only partly understood, as in the case of odors; but the fact of discrimination is well established for all senses.

As we shall see in a later chapter, a most important characteristic of the discrimination function for any sense is its *limit*. Accordingly, the psychologist has devoted much attention to the determination of limits of discrimination. He has attempted to determine, for each of the senses, what is the smallest amount of difference in physical stimulation which can be discriminated by the human individual. The limits of discrimination set the limits of behavior, since they determine what kinds of energy changes can be reacted to and which cannot.

Here, then, is the first and one of the most basic loops which is added to the framework of the simple transmission system. Without it, the organism would react the same way to any stimulus of sufficient intensity. With it, the human animal is able to respond differentially to many different stimuli. Since we do not know how the neural connections in the brain enable him to do this (except in a very general sense), let us simply represent this type of mechanism by means of a loop diagram. Figure 3.1 illustrates the function of discrimination. The "discriminator" we have postulated to account for the behavior we observe in discrimination. It is a mechanism which enables the individual organism to "sort out" the stimuli that bombard him, and to connect different stimuli with different responses.

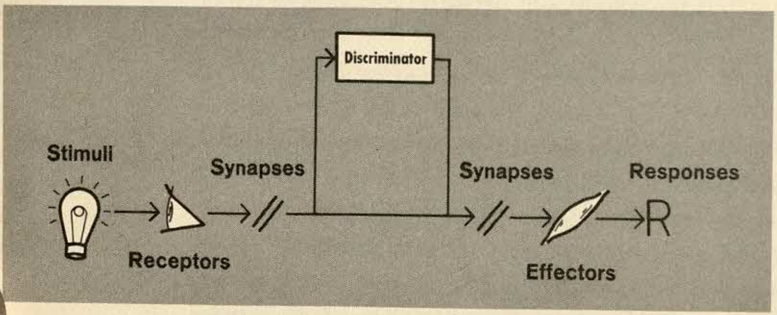


FIGURE 3.1. *Loop diagram of the Discriminator Function.*

LEARNING AND MEMORY

Assuming that the basic capacity for discrimination exists within the behavior system, how does the organism come to connect different responses with different stimuli for the first time? In other words, how does it "know" which different responses to employ in expressing this discrimination? The answer to this question leads us to two of the most important characteristics of the human behavior system, *learning* and *memory*.

Learning

The human infant does not, in fact, possess the means of expressing more than a few of the discriminations it is capable of making. Nor do the neural connections underlying such expression come into existence, so far as we know, simply because of internally regulated growth processes such as those which govern the growth of trunk, limbs, and other organs. Instead, they are acquired by a process called *learning*, which is a process of acquisition of functional neural connections called *habits*. Learning occurs whenever certain feedback effects from the environment are present at the time responses occur.

We shall have more to say about the process of learning in a later chapter. Here, let us illustrate it in a simple form which has been extensively studied by psychologists, using a white rat as a subject. A hungry rat is placed in a box with two hinged doors which he may open by pushing. Each door may be covered by either a white card or a black card; in other words, two different stimuli may be presented which differ in the intensity of light reflected from their surfaces. Let us assume we want to discover whether this rat is capable of *discriminating* these two stimuli. This means we must get him to exhibit his capacity for discrimination by means of two different responses. We do this by arranging the environment in such a way that the two responses will produce different feedback effects on the rat. This may be done in this case by making sure that whenever a door contains a white card and is pushed, a bit of food is obtained; and whenever a door is pushed when it contains a black card, no food is obtained.

Initially, the rat in the box exhibits many responses; his behavior is to a large extent undifferentiated. He sniffs the air; he runs around the box; he scratches the sides of the box. By chance, he bumps against the hinged door with the black card; nothing significant happens. On another occasion, he pushes the door with the white card, and comes in contact with some food, which he eats. Now, the next time he is put in the box, one can observe a significant change in his behavior. He tends to go more directly and more swiftly to the white card; while at the same time other responses, such as scratching the sides of the box, are reduced in extent. Once again he eats food after pushing against the white card. After a few instances of this kind of environmental feedback, the rat is seen to have *acquired some* *dependable habits.* He responds differentially by *pushing* the door with the white card, and by *avoiding* the door with the black card. In this way, we are able to demonstrate that the capacity for discriminating these two light intensities exists in the rat. But more than this, we are able to demonstrate the existence of the extremely important process of learning. Whereas originally the rat responded to a black card and a white card in an undifferentiated way, he now responds with the habits of *pushing* and *avoidance.*

Memory

It is evident that the animal not only acquires new habits, but he also stores them. If we return this same rat to the box tomorrow, he will again exhibit much the same behavior; that is, he will again tend to avoid the black card and push against the white card. The human being who has differential responses to red and green lights (such as the words "red" and "green," learned in childhood) doesn't have to acquire them all over again every time he is asked to discriminate these wave lengths. Instead these differential habits are *retained,* or *stored* by means of a neural mechanism called *memory.*

Here we come to an interesting variation on the analogy between machines and men. The "program" of a modern computing machine is determined by the designer of the machine and may be fed to it by means of a punched card, drum, or magnetic tape. The designer determines, for example, which of a variety of types of mathematical operations will be used by the machine in appropriate calculations. In contrast, the human being has a "program" which is stored in human memory, and which is determined by the learning process. Whereas the designer can change what is programmed in the machine by altering a tape or an internal circuit, a change in what is remembered by a human being must be built up by learning. Most of us, for example, in reading time from a clock, have not acquired habits which differentiate, say, between times like 5:05 and 5:06. Yet people whose jobs require them to respond differentially to such stimuli, like radio announcers or train dispatchers, readily learn habits which express these and much finer discriminations. The capacity for discrimination is not necessarily greater in these people, but their habits (which are retained by memory) are indeed different from those of many other people.

The marvelous function served by the learning process, then, is that it determines the programming of human behavior. The rat and the human being alike may come to acquire more or fewer habitual responses to different stimuli by means of learning; or, of course, they may acquire entirely different sets of habits by the same process. If, for some reason, it becomes desirable that human automobile drivers react to a green traffic light by depressing an automobile brake and to a red light by depressing an accelerator, the "memory program" could be changed by the process of learning. Or, if future automobiles should replace foot depression of accelerator and brake with push buttons, new habits of this sort could readily be learned.

As we have emphasized already, the human memory is not conceived as a device for the passive storage of facts or numerical values, as is true of some of the "storage" capacities of machines. What is learned, and what is stored, are *patterns of connections* between signals and responses, called *habits*. For this reason, we have drawn the analogy between the human memory and the program of a machine. All of the memory functions to be discussed subsequently should also be considered as belonging in this category of programming. The first of these, memory for simple habits, is diagrammed in Figure 3.2.

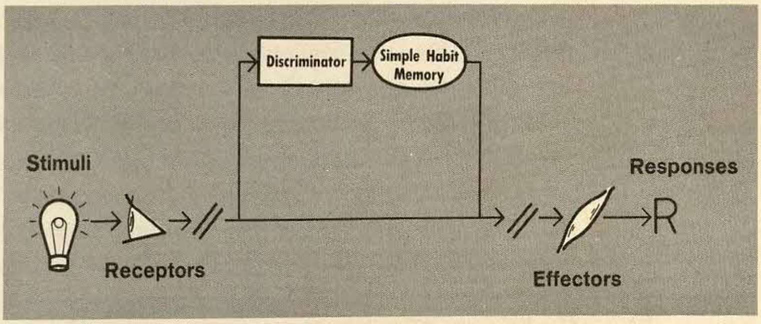


FIGURE 3.2. *Loop diagram of Simple-Habit Memory, showing its relation to the discriminator function and to the reflex connections of the behavior system.*

In this figure, we have called this function of storage of acquired neural connections "simple-habit memory," to distinguish it from other storage functions to be described later. It is placed in an *oval* box to indicate that it is a kind of program which may be modified through learning. In contrast, the *rectangular* box used for the "discriminator" function is intended to distinguish a behavior system function which, though it may vary from person to person, cannot itself be modified by the learning process.

The adult human being has built up by previous learning a tremendous variety of functional neural connections which are stored in his simple-habit memory. He can use any of these whenever he is called upon to make a discrimination. He may nod or shake his head, say "yes," "no," or make any other of a great variety of verbal responses, move his limbs, blink his eyes, or wave his hands. While we assume that each of these was *originally* learned in some *specific* situation or situations requiring discrimination, these habits are well established in the adult, and may easily be transferred from one discrimination situation to another. On the other hand, if we want the human being to use some new differential habits which conflict with old ones (such as shifting gears in an automobile by pushing buttons), we must arrange a new situation in which he can learn them.

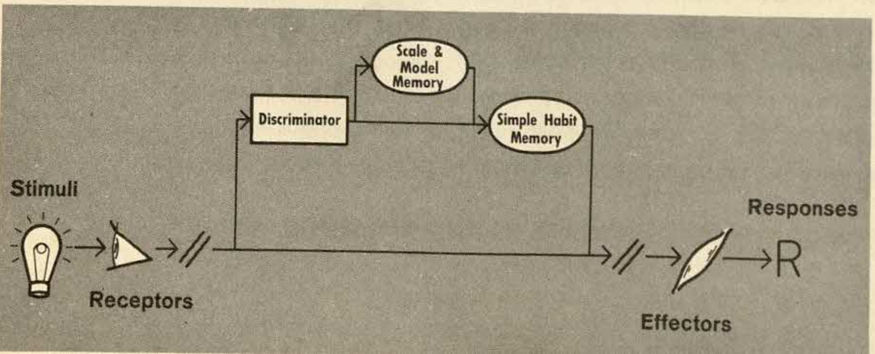
MEMORY FOR SCALES AND MODELS—IDENTIFICATION

In making differential responses, it is evident that the human being often does more than simply exhibit different reactions to two or more different stimuli. He is also able to *identify* stimulus qualities in terms of a *remembered model* or *scale*. When we show an individual a single light of given wave length and ask him to identify its color (or ask him whether or not it is green) we expect him to make a differential response in terms of a stored model of "green." In contrast, the simpler discrimination situation would be to show him two lights of different wave length and ask whether they are the same or different. But in *identifying*, a remembered standard must be involved, since only one light is present.

We make use of our memory for scales and models whenever we are required to make a response in terms of some absolute category. *An identifying response may be said to occur whenever the individual makes a response which identifies a difference (or lack of difference) between a present stimulus and a remembered standard which is not physically present.* All of us "carry in our heads" common scales such as those of length, time, weight, and models such as those of color, straightness, curvilinearity, roundness, and perhaps even harmoniousness. This mechanism may be conceived as a parallel loop leading from the basic discriminator function, as indicated in Figure 3.3. It is a memory function established by learning.

There are obviously great differences between individuals with respect to their stored scales and models, depending primarily on what they have learned. Some people are much better able to estimate absolute distances

FIGURE 3.3. *Loop diagram of the Scale and Model Memory Function. The storing of scales and models makes possible* identifying responses.



than others. Some people are able to identify many more colors than others. Perfume experts are able to identify a great variety of individual odors. Trained musicians are able to identify absolute pitches (in some cases, with a very small degree of error). A skilled carpenter may be able to identify the straightness of a board's edge better than most of us can.

The scales and models which most of us have stored in our memories are quite gross, relative to the discriminations we are able to make. We can *discriminate* between the lengths of two straight rods about 36 inches long which differ from each other by only a fraction of an inch; yet most of us are unable to *identify* lengths in this range to any finer degree than 3 inches. We can discriminate about 128 differences in color in passing along the spectrum from the red to the violet end, assuming that we have normal receptors (i.e., are not color-blind). Yet most of us make no more than six identifications (red, orange, yellow, green, blue, violet) for spectral frequencies of light.

Learning can bring about very great changes in the precision of these remembered scales and models. Musical training, for example, builds in remembered scales and chords which make possible identifications of musical patterns that are impossible to the untrained person. The deaf person learns a set of models of lip movements which makes it possible for him to identify these to an extent that far surpasses the rest of us. But most of us could learn such scales and models, if we took the time and were highly motivated to acquire them. The greatest differences are not in our basic discrimination capacities, but in our scale and model memories. The "sharpening of the senses" which takes place by learning does not, so far as we know, alter the basic capacity of the senses; but it does alter markedly the stored models and scales that enable an individual to identify stimulus differences.

The models which are acquired by an individual may be quite complex, and also difficult to describe exactly. When an individual first attempts to look at living cells and other small entities through a microscope, he usually experiences great difficulty in identifying anything except a differentially shaded round field of view. By continuing practice in comparing what he sees with printed pictures, he eventually acquires a set of models that enables him to identify a collection of cells, a bacterium, a vacuole, and many other things. Having once acquired such models, his identification of new entities is made much easier. A similar instance occurs in the interpretation of terrain features on a radar scope. To an individual who sees one for the first time, the appearance of a radar scope conveys little except irregular light and dark patches. The operator of such a machine must learn to identify terrain features, and match them with parts of maps or aerial photographs. He learns to do this by acquiring complex models which are stored in his memory. Most of us listen to music in terms of harmony based upon the tonic scale. To appreciate music built upon a twelve-tone scale, we should have to acquire a new model, a new way of identifying dissonances. This can be done through learning. Although there can be little doubt of their existence, the exact description of such complex models and scales is a difficult task.

MEMORY FOR MOTOR AND VERBAL SEQUENCES

Another important parallel loop in human behavior is one which comes into play in integrated response-sequences called *motor skills*. *A motor skill is a sequence of habitual responses the order of which is partially or wholly determined by sensory feedback from preceding responses.* Walking, for example, is called a motor skill because each succeeding response in the sequence is affected by sensory feedback from the immediately antecedent response: (1) the left leg is lifted, providing sensory feedback from the muscles of this leg, as well as changes in pressure stimulation on the sole of the right foot; (2) in response to this stimulation, the left leg is extended and touches the ground, providing a different pattern of muscle and pressure stimulation; (3) again in response to this different pattern of stimulation, the right leg is drawn back, providing a new set of sensory stimuli from the muscles of the right leg and the sole of the left foot; (4) in response to this new stimulation, the right leg is drawn up; and so on. The total skill is a highly integrated sequence, in which a continuously changing stimulus-pattern is produced by a graded set of antecedent responses.

This kind of behavior is distinguishable from simple habit, although the making of learned differential responses is involved at every step. In a motor skill, though, it is not simply a matter of lifting a leg *vs.* not lifting a leg. Instead, connections which determine the entire *sequence* of behavior are stored in the memory. Many common examples attest to this fact. A human being can make the responses connected with walking even when suspended in air. A man can run through the approximate sequence of tieing a tie without having the tie present. A musician can run through the entire sequence of finger placement in a musical selection without his instrument being present. Of course, under such circumstances the responses made may be measurably different in force and timing than they are when the entire stimulus-situation (the ground, the tie, the musical instrument) is actually present. But there is nevertheless an observable sequence of habitual responses which is capable of being enacted because it is stored by the nervous system.

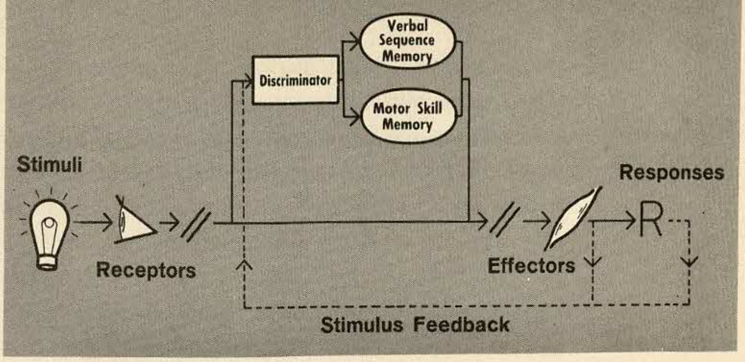


FIGURE 3.4. *Loop diagram of the Motor-Skill Memory, showing stimulus feedback. The Verbal-Sequence Memory, which has many similar formal characteristics, is also shown.*

The simplest conception one can have for motor-skill function is illustrated in Figure 3.4. This loop diagram shows only the most basic characteristics of motor skills as we have described them here. Some of the more detailed conditions of acquisition and retention of such skills will be discussed in Chapter 8.

According to this diagram, impulses from sensory nerves, after passing through the discriminator, stimulate the initial response of the sequence stored in the motor-skill memory. This response produces effects which are detectable directly by the kinesthetic sense, and also by other senses such as vision or touch. (Besides the "feel" of the leg movement, there are changed pressures in the sole of the foot, and altered "sights" caused by changes in the body's position). These stimulus events constitute a true "feedback loop" in control of subsequent responses. If the first response in the sequence has been in error by being too large, a correction is applied to the next response, so that the total sequence has the characteristic of a smoothly regulated series of actions. The basic pattern of the skill, as distinguished from these moment-by-moment corrections, is retained in the motor-skill memory, where it has been established originally by a process of learning.

DISCRETE AND CONTINUOUSLY GRADED MOTOR SKILLS. There are some common variants in motor skills which deserve mention, even though they show no basic differences from the pattern here described. Some motor skills appear as sequences of discrete steps, whereas others are sequences of continuous response-gradations. An example of the first type is the skill involved in playing a specific musical composition, where each successive note or chord may be considered as a step in the total sequence. An example of the second type is the skill of riding a bicycle, where the total set of responses, although obviously sequential in character, is also continuously graded, so that the successive steps can be only arbitrarily identified. This is true also of our previous example, walking.

Source of Feedback in Motor Skills. Some motor skills are primarily controlled by internal feedback from the muscle sense, whereas others are primarily controlled by external feedback arriving through other senses. The skill of walking, as we have said, is relatively little affected by depriving the individual of feedback from visual and pressure senses. This might be done by requiring a blindfolded individual to "walk" while suspended in air. On the other hand, one could obviously not shoot a basketball accurately if he were deprived of sensory feedback from the basket, the backboard, and the court. There is a well-known difficulty in reinstating the exact sequence of responses required in buttoning, when one does not have the usual feedback from the sight and feel of button and buttonhole. One of the properties of motor skills, then, is the degree to which they are controlled by external sensory feedback as opposed to internal (kinesthetic) sensory feedback.

Verbal Sequences

Another variant deserves special mention because it is so peculiarly and importantly a human function. Verbal sequences such as the recitation of the alphabet, the multiplication table (when recited as a sequence), and a great variety of poetry and prose passages, slogans, jingles, mottoes, etc., all have a formal similarity to motor skills which are nonverbal. The process of learning verbal sequences of this sort is subject to much the same general rules as is the process of learning motor skills. Likewise, these verbal sequences are controlled and corrected by stimulus feedback in much the same way as nonverbal skills. Typically, verbal sequences have the characteristics of being composed of *discrete* responses (usually, the individually stated word), and of being controlled largely by *external* feedback (hearing or vision).

Obviously, the verbal-sequence memory has a tremendous capacity, which is seldom used to anything like its full extent by the average human being. Some people amaze us with the repertoire of stored prose and poetry passages they have memorized. People have been known to memorize a whole book, or even several books. Individuals with mathematical interests may memorize long number-sequences, and recite them at will. Another convenient property of the verbal-skill memory is that specific sequences are readily "erased" or forgotten after relatively short intervals unless particular pains are taken to reestablish them by additional learning. The poetry passage we learn in grade school for tomorrow's recitation fades away in a few days or weeks unless it is relearned. Although there may be "interference" between two successively learned sequences, as we shall see in a later chapter, there is no evidence concerning the limitation of the verbal-sequence memory. Presumably, any one of us could increase his number of memorized verbal sequences a hundredfold, simply by undertaking the necessary learning. Of course, such learning would take time.

Fortunately, we do not have to depend upon the verbal-sequence memory for the reinstatement of many verbal responses, because we have another "higher-order" loop which works much more efficiently. We can recall what we read in a textbook, for example, by means of our "concept memory," to be described shortly. Briefly, this mechanism enables us to store the *meaning* of what is read in simplified form. We can then reinstate it in this same meaningful form without repeating it word for word. If the student had to pass examinations by depending only on his verbal-sequence memory, his life would indeed be full of dull chores. As it is, he uses his verbal-sequence memory in the storage of only a relatively few prose passages, verses, formulas, and the like, and depends upon the learning and storage of *concepts* for the major part of his education. It is largely for this reason, apparently, that most of us use only a minor portion of our verbal-skill memory capacity; the more efficient process of concept formation makes this unnecessary.

MEMORY FOR CONCEPTS

If we were to stop with our model of a behaving human being with mechanisms which enable him to discriminate, to identify, and to respond sequentially, we should have something comparable in many respects to an animal. The first prominently human function we have to describe is man's ability to learn, store, and use *concepts*. It is this ability which enables man to exhibit behavior which is based upon "abstraction" or "generalization" from the great variety and number of individual stimulus-situations which he encounters. It is this which makes it possible for man's behavior to be determined by classes of objects, by rules and principles, rather than by individual stimuli which arouse specific habits and their associated responses.

Concepts are verbal in character, and it is this aspect of man's language behavior which is so completely distinctive from animal behavior. Everyone knows that certain animals, such as parrots and parakeets, can acquire speech habits; in fact, some of them can learn and store in their memories a tremendous repertoire of speech responses and sequences. Furthermore, even animals who are incapable of expressing actual words (such as dogs, monkeys, apes, and many others) may nevertheless readily acquire vocal habits which serve as signals to other animals. A squirrel's chatter has this type of signaling value to other squirrels. A dog's bark stimulates other dogs to bark. An animal can be trained to make a particular kind of vocal sound at the verbal command of his human master. All of these examples indicate that there is nothing peculiarly human about speech sounds as such. Nor is there anything particularly remarkable in the fact that vocal sounds (from a human being or other animal) can acquire, through learning, a signaling value for habitual responses of animals, just as any other nonverbal stimuli can.

As we consider animals with larger and more complex nervous systems, we begin to encounter increases in their ability to respond appropriately by generalization to various new situations. We can train a household pet to go to the back door of the house when we say "Back!" and to the front door when we say "Front!," starting in each case from some specific outdoor location. Furthermore, in a limited manner, this habitual response may generalize to other similar houses and similar locations. But the degree of generalization is small indeed, compared with the amount exhibited by higher animals which can do the equivalent of "saying to themselves" "front" and "back." Using these as concepts, we can guide the behavior of the human being in a tremendous variety of specific situations. We do not have to begin from the same location, and we can apply "front" and "back" as concepts, without specific additional learning, in controlling our responses to an almost limitless variety of houses and other structures.

Another difference in the concept mechanism between animals and men appears to be the capacity for storing these verbal signals over a period of time, which is possessed to only a limited degree by animals. Having trained our household pet to respond appropriately to the words "back" and "front," we cannot expect him to respond correctly if we provide these signals in a location that is as much as an hour away from home, because he cannot retain and reinstate "Back!" or "Front!" when he arrives there. To a human being, even a child, we could say "When we get home, go to the back door," and expect an appropriate response an hour later. The critical difference is not in the fact that we have used a sentence, rather than a single word of command. Instead, the important difference is that the human being has been able to store and use a general class-word ("back" or "front") to guide his behavior over a reasonably long interval, whereas the animal has not. By exercising careful control, we may be able to get an animal to delay a previously learned response to a specific stimulus for several minutes, and then to perform correctly. But the human being is able to store and reinstate such words (whether to himself or aloud) for hours, days, and years.

As much work with rats in mazes has shown, it is fairly easy to train an animal to take a specific path from a starting box to a goal box containing a piece of food. Animals can learn to make a variety of turns and to avoid blind alleys within a fairly short time. But what an amazing difference there is between this specific skill and the ease with which we can direct a human being's progress along an unknown path! We can say "Take your second left; turn right at the first stop light; then take your third right," and a man gets there! At least, he is successful if he has taken the trouble to store the words "Second left; stop light, right; third right" or their equivalents, and can therefore use them to guide his behavior. He may be in an entirely strange neighborhood, in which nothing is familiar; yet the directions he has just acquired are quite adequate to guide him.

Animals like white rats can learn skills of great complexity, controlled by external stimuli such as the specific visual, auditory, tactual, and olfactory stimuli of a maze. But they cannot, apparently, learn and retain a rule which will guide them in a *new* pathway in which these external stimuli do not appear. The human being does this with language, and the verbal names and phrases he stores are called *concepts.*

A concept is a stored set of connections in which a verbal signal controls the arousal of habits appropriate to new situations, so that the learning of new specific habits is unnecessary. When we introduce two people who have not met, saying "Mr. X is the president of Y Company" the word "president" signals the arousal of habits in the second person which perhaps include responses indicating deference and respect. If, instead, we were to say "Mr. X is a convicted kidnaper," the habits aroused and the responses exhibited would presumably be quite different. But in either case the functioning of the concept is the same. The entire set of appropriate habits is reinstated in the individual immediately upon hearing the word "president" or "kidnaper." He does not have to go through a new period of learning appropriate responses of greeting. Furthermore, the same general concept will be retained and used again in other new situations. The concept enables the individual to generalize appropriate responses to a great variety of specific situations.

Initially, of course, concepts are themselves learned, and they are also modified by learning. A child must learn appropriate habits of responding to the verbal signal "president," just as he must to simpler concepts such as "table" and "chair." A child of ten may not exhibit the sort of responses in greeting a stranger who is introduced as "president of Y company" that are considered appropriate by an adult. The grownup has learned and been rewarded, by social approval or otherwise, for the exhibition of deferential and respectful responses to this signal. *The meaning of any concept is to be found in the entire set of specific habits it arouses.*

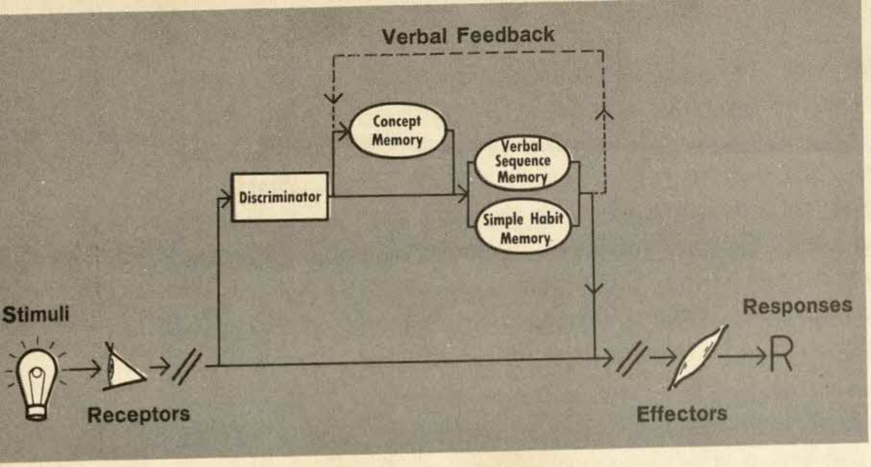


FIGURE 3.5. *Loop diagram of the Concept Memory. The diagram shows the stimulus-feedback loop by means of which the individual may supply retained words or verbal sequences to arouse concepts.*

And the meaning of a concept changes as a result of the learning experiences of the individual. The simplest and most widespread meaning of "chair" is the response of sitting down. To a furniture-builder, however, "chair" has come to have a meaning considerably richer than this, because it can arouse in him a whole set of habits and skills related to the shaping of the seat, the fitting of the legs, and so on.

The concept memory is, then, another highly important behavioral function which we must indicate in our functional diagram, Figure 3.5.

In this figure, the concept memory is represented as another parallel loop which may control the input to the simple-habit memory and the verbal-sequence memory. The flow of events is conceived to be as follows: The stimulus is provided when the individual hears a spoken word such as "chair." This is received and discriminated from other similar-sounding words. This signal then arouses in the concept memory an (unspoken) response which symbolizes "chair." This in turn gives rise to a total complex of signals for the arousal of whatever specific habits and skills have previously been learned in connection with the concept "chair," including the act of sitting down.

There is also a stimulus-feedback loop to be accounted for in the mechanism pertaining to concepts. Rather than hearing or seeing a word, the individual may supply it himself. As we have previously pointed out, the human being is able to store specific verbal habits like "back door," or longer sequences such as "second left; stop light, right; third right," and then *to say them back to himself*. These self-provided signals feed back to the concept memory, and arouse unspoken verbal concepts which in turn become signals for appropriate overt behavior. It should be mentioned that the feedback loop may, on occasion, be a somewhat longer one. This would be true if the individual actually spoke the phrase "back door" out loud. In this case the signal provided by the spoken word would function as an external stimulus to arouse the concept. We all do this sometimes, but there is no particular reason to believe that the feedback has to be overt, or that it must involve muscular responses and receptors. Presumably, a shorted connection within the central nervous system is entirely possible, as shown in Figure 3.5. In either case the function is the same: a specific verbal response functions as a signal to arouse habits appropriate to new situations.

Types of Concepts

The use of verbal concepts is such a prominent and widespread kind of human activity that it is difficult to describe adequately all the types of behavior to which such use applies. Here are some of the types of concepts which are easily recognized:

CLASS CONCEPTS. Relatively early in the life of the human being, common objects come to be responded to in terms of class concepts such as "table," "chair," "mother," "father," "house," "cat," "come," "go," "up," "down" and so on. At first the child simply acquires simple habits of responding to the word "father." At the age when he can merely "walk to father" (as opposed to mother or some stranger), we cannot yet be sure he is employing "father" as a concept. But certainly he must be doing so by the time he is able to identify "John's father" or "Mary's father" as well as as his own father.

In the adult, a great proportion of behavior is controlled by means of class concepts. The worker on an industrial job receives most of his instructions by means of verbal concepts, whether oral or printed. When a worker is provided with the printed instructions "First turn 'power' switch to the right one-half turn," it is assumed that previous learning has enabled him to control his behavior by means of such concepts as "turn," "switch," "right," and "one-half turn."

RULES. Much of our behavior is guided and controlled by verbal rules such as "Look both ways when crossing the street," "Don't pass on a curve," "*i* before *e* except after *c*," and others. The many rules of grammar, spelling, and arithmetic calculation ("Invert the fraction and multiply") fall into this category. In common with other concepts, such verbal rules which we "say to ourselves" enable us to generalize habits and skills to various specific new situations. It is important to note that a rule by itself is of little use unless the habit or skill it controls has already been learned. Thus it is of little use to know the rule "Invert the fraction and multiply" if one does not know how to multiply. The rule of lining a car up with the back of a parked car in parallel parking is useful only if it can be used in connection with the well-learned skill of backing into place. It is sometimes said that common rules like these are quite ineffective in controlling behavior. But such difficulties can often be traced to the more fundamental habits or skills, rather than to the operation of the rule as a concept.

ABSTRACT CONCEPTS. Abstract nouns which do not refer to a class of concrete objects, such as "integrity," "beauty," "patriotism," "justice," "democracy," also have a controlling effect upon behavior which is fundamentally similar to that of other concepts. These words may arouse a whole complex of other class concepts and rules, which in turn control a variety of habitual responses, depending on the individual's past learning. Included in these may be habitual emotional responses, like those aroused in many people by the concepts "atheism" or "communism."

COMPLEX PATTERNS AND SEQUENCES. Concepts may take the form of fairly complicated patterns or sequences of simpler class concepts. The use of such concept-sequences takes place in the human activities of reading and writing (composition), for example. When an individual follows the "thread" of a verbal exposition or story, he is dealing entirely with sequences of concepts, none of which controls his immediate overt behavior. The solution of mathematical problems is also a matter of using concept-sequences, which often involve a preponderance of shorthand symbols rather than words.

Communication among human beings is obviously carried on primarily in terms of sequences of concepts. The biological utility of this kind of behavior is tremendous. It means that the human being does not have to experience directly, or "learn by doing," all the various specific responses which come to be controlled by concepts. Instead, he can proceed directly from concept to concept in a sequence which leads to an ultimate response. He can vicariously experience the important events of the lives of many people, real or fictional, by following sequences of concepts contained in books. He can follow the derivation of a final specific mathematical concept without stopping to perform the activities (such as summing, multiplying, etc.) implied by each term encountered along the way. By reading and following printed concept-sequences, he can acquire the wisdom of previous generations of human beings.

Use of Concepts in Thinking

One of the most interesting and important functions for which concepts are used by the human being is that of *thinking*, or *problem-solving*. This activity has often been described as "internal trial and error." What this means is that the individual generates "trial" concepts (usually rules) which express the consequences of his behavior, and then chooses one which will best accomplish the desired result (solve the problem). Two or more alternative concepts are "weighed," and one is selected to determine a course of action. This process may take place in a sequence of steps involving successive acceptance or rejection of alternative concepts.

In thinking out a problem concerned with meeting an appointment, a man may say to himself, "If I leave my house at 12:30, I shall arrive at the corner of Dayton and Grove Streets at about 12:45; if I arrive there at that time the traffic will slow me up ten minutes in getting downtown; if I am slowed up this much, I shall arrive five minutes late for my appointment; if I am even one minute late, I shall miss the man I want to see"; (another trial) "if I take another route downtown, this will take fifteen minutes longer; that means I shall be even later"; (another trial) "if I leave at 12:20, I shall be on time." Note that, in this example, the concepts follow each other in a typical sequence. The dominant concept "leaving at 12:20" is the one which is selected to control the habits (and thus the overt behavior) later to be exhibited.

As we have said, thinking of this sort is subject to *verification.* Suppose this thinking is wrong, and the thinker in this instance arrives late for his appointment, after having left at 12:20. He may then acquire one or more new concepts, depending on the circumstances he has met. For example, he may learn that traffic at Dayton and Grove means a 20-minute (rather than a 10-minute) delay. Or the man he is meeting may say, "Oh, I am always ten minutes late for an appointment," thus giving him an important new concept to store and recall in future dealings with this man. On the other hand, the thinker may meet his appointment on time and thus verify the correctness of the concepts used. Verification is obviously a crucial part of clear thinking, as well as the basis of all new knowledge. There are certain psychologically disordered people who are quite capable of thinking logically, but who, for some reason not well understood, fail to respond to feedback from verification ("I am Napoleon!"). These unfortunate people cling tenaciously to concepts which resist the change that usually comes from verification.

SUMMARY

Now let us step back and survey what we have learned so far about human behavioral functions. We need not only to review them, but to acquire them as concepts, since we shall have more to say about them in subsequent chapters.

Built upon the basic pattern of signal transmission in the human behavior system is the function of *discrimination*, which enables man to differentiate the signals arriving over sensory nerves. He may exhibit this differentiation by means of *simple habits*, which have been acquired through a process of *learning*, and which are *retained* or stored in *memory*. He may also retain sequences of responses called *motor skills*, which are dependent for their accurate expression on *sensory feedback* arising from external stimulation (such as visual) or from internal stimulation (as from the kinesthetic sense). A special category of such response sequences are verbal, and include remembered phrases, slogans, formulas, prose and poetry passages. These are usually spoken of as *verbal sequences*.

In contrast to the relatively simple function of discrimination, we have seen that many responses of human beings to stimuli depend upon their possession of internal *models* and *scales* which have been learned and stored, and which make possible the *identification* of stimuli in terms of some remembered standard. Many properties of stimulation may be thus identified, including length, time, weight, color, harmony, and a great variety of others. Relatively complex models and scales, whose dimensions are difficult to specify, may be learned and used, as in odor identification and radar-scope interpretation.

A primarily human function involves the learning, retention, and use of *concepts*. These are verbal responses which, through a feedback mechanism, become *signals* which determine the arousal of other habits and skills. Concepts make possible the *generalization* of available responses to new situations, without the necessity of specific learning. They also can be stored for long periods of time to control *future* behavior. We have mentioned four common types of concepts, although this is a somewhat arbitrary classification: *class concepts* which categorize objects like chairs, tables, automobiles, furniture; *rules* which can usually be expressed as directive sentences like "Always tip your hat to a lady"; *abstract concepts* which do not denote classes of objects, but nevertheless may control a predictable set of habits in an individual, such as the abstract nouns "beauty," "honesty," "liberty"; and *concept sequences* such as those which occur in reading and composition, or in manipulation of mathematical symbols.

Finally, we have seen that concepts are used in *thinking* or *problem-solving*, in which they are compared or "weighed" in two or more alternatives at a time. One concept (usually, a rule) is selected and becomes the dominant concept which determines the habit or skill that is displayed. The responses thus determined are then subject to *verification*, which may lead to re-storing of the "successful" concept, or to learning a new or modified one.

READING REFERENCES

Hebb, D. O., *The organization of behavior.* New York: Wiley, 1949. An account of human behavioral processes and their relation to neural organization.

Hebb, D. O., *A textbook of psychology.* Philadelphia: Saunders, 1958. A basic text emphasizing neural mechanisms in behavior.

Osgood, C. E., *Method and theory in experimental psychology.* New York: Oxford, 1953. A systematic account of experiments and theory pertaining to human behavior.

Pfeiffer, J., *The human brain.* New York: Harper, 1955. A description of the functions of the brain, and of modern research in this field, in nontechnical language.

Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954. Experimental foundations of human functioning, summarizing work on discrimination, perception, skills, verbal learning, and thinking.

4

MOTIVATION

In order to complete the picture of the behavior system, we turn from our description of the classes of human activities to the subsystem which energizes behavior. This is the function called motivation. You will find described in this chapter the fundamental properties of motivation and the varieties of human motives. Also, we pay attention here to the ways in which incentives are used to control human behavior, and the effects which changes in motivation have on human performance.

What we have described in previous chapters may be viewed as the sensing, "data-handling," and skill functions of the behavior system. We must now pay some attention to another set of functions: the "energizing" functions. What activates the human being to use his verbal, thinking, or motor skills? How does his behavior over periods of time become directed to obtaining some end or achieving some goal? These are questions about the *motivation* of behavior. The problem of bringing an individual's abilities and skills to the level of actual performance is one of motivation. Without motivation we have a behavior system which does not work because no "power" has been applied.

HOMEOSTASIS AND MOTIVATION

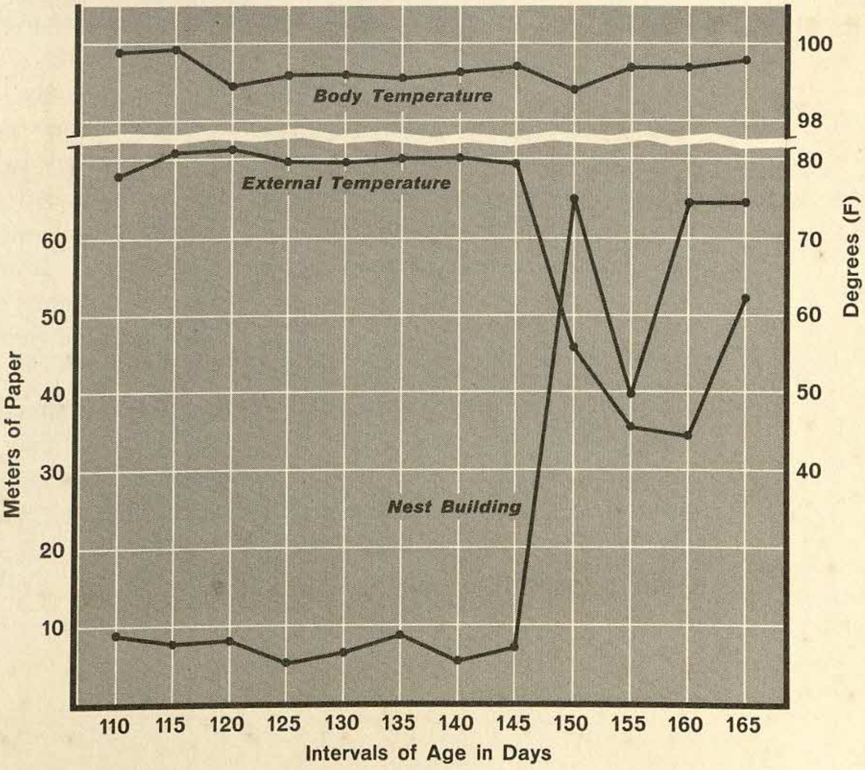
Under what conditions is the behavior system "energized" (or motivated)? And how is it that only certain behavior functions become energized at particular times? How does the energy get channeled into specific activities?

Motivation—a fundamental characteristic of life—arises from the tendency of living systems to maintain constant states of equilibrium in bodily processes. It is an important physiological principle that the internal organs of the body tend to maintain a constant internal environment, which is essential for the individual's survival. This principle of internal self-regulation is called *homeostasis*. For example, a homeostatic mechanism controls the chemical composition of the blood, so that it gets neither too acidic or too alkaline; and so that it contains particular concentrations of sugar and carbon dioxide. Similar mechanisms preserve the balance between oxygen and carbon dioxide.

The internal temperature of the body is likewise subject to homeostatic control, and may serve as a more detailed illustration of this principle. When body temperature falls slightly below certain critical levels, a reflex center in the brain is activated. This results in a higher metabolic rate; the blood circulates faster, and muscle tension is increased. All this serves to release and distribute heat more rapidly. Generally, the individual is unaware that this is happening. When, however, the decline in temperature continues, bodily activity becomes observable in behavior. Shivering and vigorous muscular action will help to restore the normal temperature. While some animals can fluff their fur, all that is left of this mechanism for humans is goose-pimples.

In addition to this internal self-regulation, the organism often must

FIGURE 4.1. *An example of homeostasis. While the room temperature was 80° F, little nest-building took place. When the room temperature was lowered to below 60° F (at age 150 days) the rats immediately started building nests, thus maintaining their body temperature at a constant level (approximately 100° F). (Data from* Richter, C. P., *Hypophysical control of behavior,* Cold Spr. Harbor Sympos. quart. Biol., *1937, 5, 258-268)*



restore states of equilibrium by interaction with the environment. This is what is meant by *motivated behavior.* To illustrate this, we may extend our previous discussion of temperature control. If the body temperature drops and the metabolic processes or simple behavioral adjustments (such as shivering or slapping one's arms) are not sufficient to restore the normal temperature state, more complex behavior may result. For example, in one experiment with rats the room temperature was reduced from 80°F down to 50°F. The rat's environment was arranged so that strips of paper were available. Continuous measurements of the rat's body temperature were taken. Figure 4.1 illustrates the results of this experiment. The results indicate that if the rat's body temperature drops, and the metabolic adjustment is not sufficient to restore the equilibrium, he will build a nest of paper or other available materials. In other words, he interacts with his environment and this interaction restores the equilibrium. As the figure shows, body temperature was kept constant throughout.

The term *motivation,* then, refers to behavior that is instigated by some kind of disequilibrium or deficit within the individual and is directed toward goals that can restore the equilibrium (or reduce the deficit).

Needs, Behavior, and Goals

In everyday terminology a number of different terms are used to describe different aspects of motivation. For scientific purposes we need to define these more precisely. First of all, motivation may be described in terms of a sequence of events with three stages. These include the *need,* the energized behavior resulting from the need, and the *incentive* (or *goal*) which satisfies the need and brings the activity to a halt.

Need is the term most commonly used to designate the state of disequilibrium we have talked about. Thus, a need is some deficit within the individual. Later we shall discuss the varieties of *physiological needs,* such as lack of food or water, and *acquired needs,* such as needs for prestige and affection. The term *drive* is often used interchangeably with need, particularly when physiological needs are being referred to. It adds the implication that needs provide impetus to behavior. An animal with a need for food is driven in search of food. Thus a drive (or more generally, a *motive*) implies direction toward some particular goal.

The second stage of the motivation sequence is the behavior that results from the impetus of the drive. This behavior may be reflexive or instinctive behavior, such as that shown by suckling animals. It may be general restlessness such as that shown by a hungry, crying infant. Or it may be highly complex learned behavior such as that of a scientist carrying out an experiment.

The third stage of the motivation sequence is the *goal* or *incentive* stage. Behavior is directed toward the goal in order to reduce the need or drive. The hungry rat has the goal of eating. The affection-starved man may have the goal of marriage. In these examples the incentives may be a piece of cheese and a pretty girl, respectively. The sequence ends in a goal response (sometimes called a consummatory response).

We may summarize this sequence as follows:

$$\left.\begin{matrix}\text{deficit}\\ \text{disequilibriun}\end{matrix}\right\}\text{NEED}\xrightarrow[\text{activity}]{\text{drive to}}\text{BEHAVIOR}\xrightarrow[\text{behavior}]{\text{goal-directed}}\underset{\text{(incentive)}}{\text{GOAL}}\left\{\begin{matrix}\text{deficit reduced}\\ \text{equilibrium established}\end{matrix}\right.$$

NEEDS AND ACTIVITY LEVEL. A need, when it occurs in a normal environment, typically produces heightened activity on the part of the organism. When an animal is hungry or thirsty or deprived of sexual satisfaction, his activity increases. Sleep deprivation may be a specific exception, although the unsatisfied need for sleep often does result in restlessness.

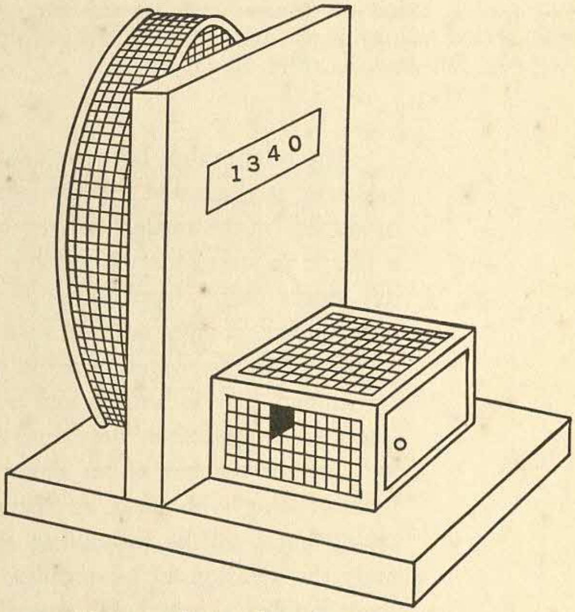


FIGURE 4.2. *An activity wheel. The animal lives in the apparatus, finding food and water on the right in the small rectangular cage. The wheel turns as he moves about and runs. The number of revolutions is recorded on counters. (From Woodworth, R. S., and Marquis, D.,* Psychology *(5th Ed.). New York: Holt, 1947)*

Many investigators have demonstrated the direct relationship between amount of need (as measured, for example, by hours of deprivation) and amount of activity. In fact, *amount of activity* is generally believed to be one of the most accurate measures of *strength of need.* Figure 4.2 shows one type of device used to study activity level. The relationship between deprivation and activity level, as measured in such a wheel, is shown for food deprivation in Figure 4.3. Similar results have been obtained with other primary drives.

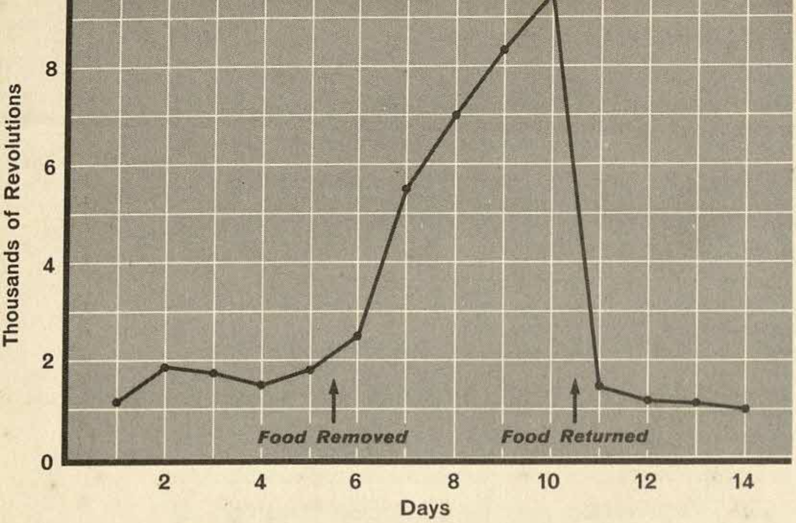


FIGURE 4.3. *Increased activity of white rats in an activity wheel, as a result of food removal. Food was removed after the fifth day, and returned after the tenth. (Data from Wald, G., and Jackson, B., Activity and nutritional deprivation,* Proc. Nat. Acad. Sci., *1944, 30, 255-263)*

The relationship between activity level and the hunger drive in infants has been investigated experimentally, by recording the motions of a crib produced by the restless activity of the child. The curve of activity shows a steady increase toward feeding time and then a falling off. During the day peaks occur every four hours, but the biggest peak is at 6 A.M., a consequence of eight hours of food deprivation.

The adaptive value of activity in motivated behavior is easy to realize. An animal that is hungry and without immediate access to food will be impelled to greater activity, and thus will run around and explore farther and farther reaches of his environment until he finds food. Likewise, a human being who faces an obstacle or problem and who is driven by a strong need will be inclined to exhibit a great variety of activity until he finds the solution to his problem and satisfies the need. In so doing, he may acquire a new habit, model, sequence, skill, or concept, which will enable him to satisfy the same need more rapidly the next time it recurs. Thus the primary adaptive function of motivation in learning is to force the individual to make more varied responses to a greater number of features of the environment until he happens upon a set of activities which satisfy the need. This set of activities then becomes learned, retained, and exhibited again the next time the need recurs. Once this has happened, the effects of the need may be observed simply as increased intensity or speed of this learned activity. But if for some reason the goal is not attained, there is a recurrence of the highly varied activity until the need is satisfied by some other means.

Thus, the *energizing* function of motivation can readily be observed. But we need also to consider in some detail a second function of motivation, namely its *guidance* or *goal-directing* function. In their energizing function, motives stimulate the individual to action. In their guiding function, motives determine the particular kinds of behavior which occur. In the remainder of this chapter we will examine more closely the specific kinds of motives which guide behavior.

First we shall turn our attention to the *primary drives,* or those based on physiological needs. Following this, we shall give some account of the *acquired motives,* or those which develop in the individual through learning. While our discussion will treat the different drives and motives separately, it should be kept in mind that behavior at any given time often results from a combined effect of several different motives. Later on we shall examine what happens when motives differ in strength or when they conflict with each other.

PRIMARY DRIVES

The term *primary drive* refers to those forms of motivation which can be directly attributed to physiological need, and which do not originate in previous learning. Primary drives are identified in both animals and men by various kinds of evidence showing they could not have been learned. Since such evidence often results from experiments in which the organism must be deprived of both the incentive (such as food or water) and of opportunities for learning, it is not surprising that many studies of drives have employed animals rather than human beings.

Hunger

When an animal is deprived of food, he becomes increasingly active, as we have seen. A human being "feels hungry" in addition to becoming restless. Some of these feelings have their origin in strong contractions of the stomach. This was shown in a famous study in which a rubber balloon attached to a tube was swallowed by an individual, inflated so that it filled the stomach, and the tube attached to a recording mechanism as shown in Figure 4.4. The subject in this study pressed a key whenever he felt pangs of hunger. This recorded a mark on a moving tape. His stomach contractions, which exerted pressure on the balloon he had swallowed, were also recorded on this tape, as Figure 4.4 shows. When the records were analyzed,

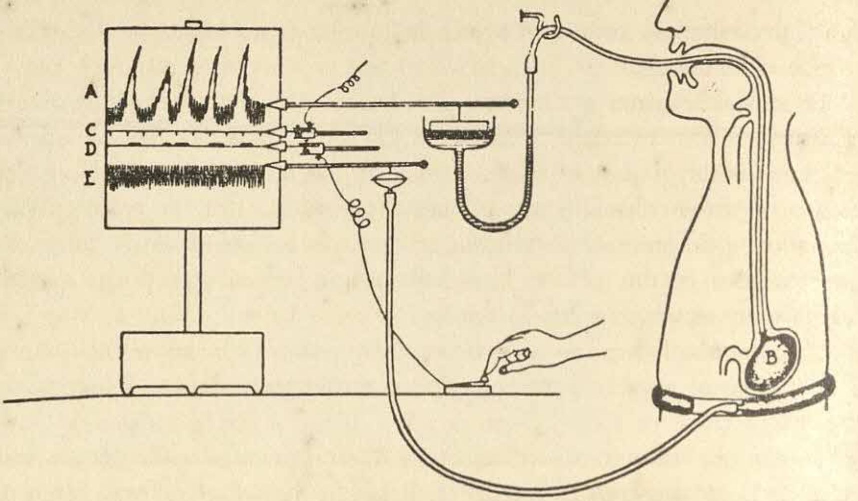
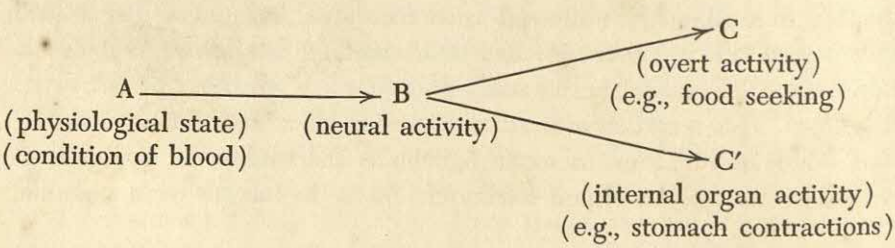


FIGURE 4.4. *The recording of stomach contractions and feelings of hunger. On the kymograph record, line A records contractions of the stomach (along with breathing movements, which are recorded separately on line E.) Line C is a record of time in minutes, while D indicates the subject's signals of hunger pangs. (From Woodworth, R. S., and Schlosberg, H.,* Experimental Psychology *(Rev. Ed.). New York: Holt, 1954, p. 659. After Cannon)*

it was found that hunger pangs and stomach contractions occurred at the same time.

Does this mean that hunger (a physiological condition of the blood) first stimulates the stomach to vigorous contraction, and that this stomach activity in turn becomes the source of stimulation that produces heightened activity? Apparently not. People who have had their stomachs removed still get hungry. Animals, after their stomachs have been removed surgically, show typical reactions in eating food, in exhibiting increased activity when deprived of food, and in learning habits that lead to food consumption. A rat without a stomach still learns a maze for a food reward. The drive of hunger, then, is not connected to activity through a causal chain that includes stomach contractions. Instead, both stomach contractions and other activities have the same fundamental basis; perhaps contractions of the stomach are simply an "internal" form of heightened activity.

The mechanism of hunger, and quite probably of other drives as well, exhibits the sequence:



The physiological state (or need) in hunger is a condition of the blood, which cannot be precisely specified at the present time, although some aspects of its chemistry are known. The overt activity can be readily observed and measured, as can the activities of internal organs like the stomach. The least well-known part of this sequence is the neural activity. However, it has been shown that electrical stimulation of a part of the brain called the *hypothalamus* produces high amounts of overeating in cats.[1] Surgical injury in one region of the hypothalamus in animals produces a marked increase in eating; injury to another portion causes eating to stop.[2] The hypothalamus, located below the cerebral cortex, is a neural center which appears to be very important in the control of a number of drives, as we shall see.

FOOD PREFERENCES. In satisfying their hunger drives, people exhibit various taste preferences for different foods. Essentially, these are learned habits. But aside from this kind of taste preference, there is evidence that some specific preferences arise directly from specific bodily needs. A number of studies on this question have been carried out with dairy animals such as pigs, cows, and chickens, as well as on laboratory rats and mice. Typically, these animals are supplied with containers of different foods and allowed to select their diets over a period of time. The results show that animals tend to select balanced diets. Other studies have shown that rats have specific hungers for sugar, fat, protein, thiamine, riboflavin, salt, phosphorus, sodium, and calcium.

It appears that the natural capacity to select foods extends to humans. In one study, infants were provided with large trays containing 12 to 20 different foods.[3] While a baby might confine himself entirely to desserts, or entirely to butter, for several meals, it was found that over a period of time their diets corresponded closely to balanced ones. However, it should be noted that the foods used in this experiment included only those in a healthful range.

Specific hungers can be developed in people by excluding certain vitamins from their diets. Thus, if calcium is eliminated, the individual is apt to develop a strong craving for milk or other calcium-containing foods. In pregnant women the need for fats and proteins is increased, and the individual becomes strongly motivated to eat these foods. Similarly, when the adrenal glands have been removed surgically from rats, these animals lose salt constantly.[4] Following such treatment, the rats develop a preference for salt water over tap water. This is clearly a homeostatic adjustment to the specific physiological need.

Yet we are all aware that people eat foods inappropriate to the needs of the body. The main reason for this is that in human beings learned habits can override natural food preferences. In fact, in some experiments animals have been trained to prefer foods counter to their natural food preferences.

Thirst

The need for water, like that for food, has an obvious physiological basis. Water is constantly being lost from body tissues through evaporation from the skin, as well as through the formation and excretion of urine. This need produces drive phenomena similar to those of hunger. These include increased activity as time of deprivation is lengthened (again, up to a point), and increased amounts of drinking following greater deprivation. As in hunger, there is also activity in an internal organ. The stimulation associated with feelings of thirst arises from dryness of the mucous membranes of the mouth and throat. However, this condition alone cannot account for the drive. Just as stomach contractions represent only one component of the hunger drive, dryness in the throat and mouth represents only one aspect of the thirst drive. It has been shown, for example, that people and animals without salivary glands still drink water according to their body needs, not simply in conformity with the dryness of their mucous membranes.

In one study on dogs, the esophagus of each animal was led out through the skin of the neck in such a way that the water drunk by the dog ran out without going to his stomach.[5] Food and water could still be put directly into the stomach. When the dogs were offered water, they drank an amount proportional to the previous loss in body-weight produced by a water deficit, even though none entered the stomach. In other words, they drank water not in proportion to the dryness of their throats, and not in proportion to the emptiness of their stomachs, but in accordance with their biological needs. If enough water was put directly into a dog's stomach to satisfy its needs, it would still "drink" an amount equivalent to a previous deficit; but after 15-30 minutes, no drinking occurred. Apparently, the dog's thirst was satisfied after the water remained in the stomach a relatively short period of time. This evidence suggests that the chemical condition underlying thirst acts through some neural center. There is evidence that the cells of the hypothalamus are especially sensitive to loss of water, and it is believed that connections of this center with other parts of the brain regulate drinking behavior.

Sex

Another powerful primary drive is sex. This drive is specifically identified with the sequence of goal responses of copulation terminated by an orgasm. The physiological state which constitutes the need is produced by hormones in the blood stream, which in turn have been secreted by endocrine glands. The glands immediately concerned with the sex drive (whose activity is in turn influenced by other endocrine glands) are the testes in the male and the ovaries in the female. These glands produce the hormones which cause the drive; testosterone in the male, and estrogen in the female. Removal of the sex glands has the immediate effect of reducing general activity in animals, as indicated in Figure 4.5. Specific sexual activity is also reduced and ultimately eliminated by removal of these glands, although this effect is gradual and less pronounced in higher animals. Injection of hormones has been shown to restore both the general and the specifically sexual activity.

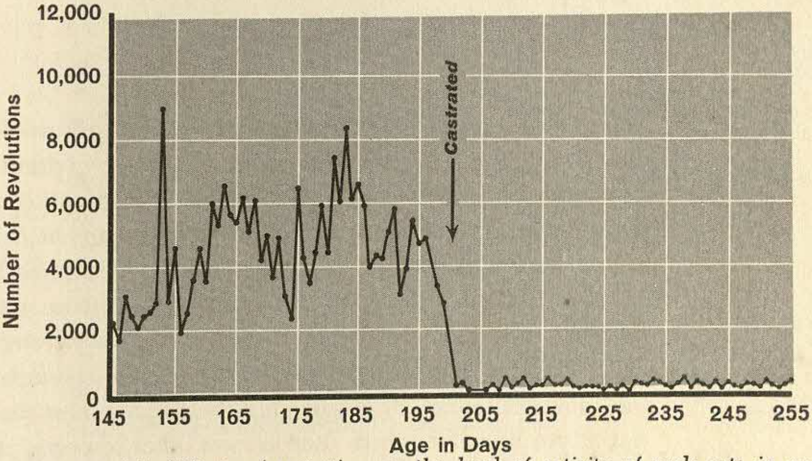


FIGURE 4.5. *Effects of castration on the level of activity of male rats in an activity wheel. Removal of the sex glands resulted in an immediate drop in activity to a low level. (Data from Richter, C. P., Animal behavior and internal drives,* Quart. Rev. Biol., *1927, 2, 307-343)*

The production of hormones in the female animal is known to follow regular cycles, producing periods of "heat" in which the animal is receptive to sexual intercourse. Cycles of this sort are present in higher animals, too, but sexual behavior is not so rigidly controlled. The female chimpanzee is to some degree receptive throughout the cycle, but shows maximum receptivity around the time of ovulation. Human females report greatest sexual desire during the periods just following and preceding menstruation; such a cycle is not directly related to hormone production.

This account of the sexual drive makes it apparent that a great deal of the activity that goes under the name of sexual behavior is neither random activity nor is it reflexive. Clearly, much of it is learned. Furthermore, the higher we go up the phylogenetic scale the more learning there is. Rats that are reared from birth in isolation mate normally the first time a male and receptive female are placed together in a cage. But this is not true for monkeys and chimpanzees. The male chimpanzee must learn to copulate, and is usually aided in this learning by an older, more experienced female.

In the human being, the sex drive is satisfied through activities that show remarkably various elaborations based upon learning. The kinds of activity which are directly associated with the goal response vary widely in human beings, as the "Kinsey reports" demonstrate. In addition, these forms of sexual activity are preceded by complex and widely differing patterns of courtship and sexual play. The human individual who is first stirred to restlessness with the development of the sex drive at puberty indeed has much to learn.

Pain as a Drive

As we learned in Chapter 2, one kind of sensory experience that may be distinguished from pressure and temperature stimulation is pain. But besides this simple experience, important motivating effects result from painful stimulation. There is little doubt that pain can act as a goad to action, or that it acts in this way without any learning having taken place. Stimuli that are "painful" in the adult arouse intense activity on the part of the very young child. Perhaps some kind of homeostatic condition within the individual is thrown into a state of imbalance when pain stimulation is encountered. If so, this state must exist in the nervous system, and it has not as yet been identified. But in most other respects, pain acts as a typical drive. It stimulates the organism to behavior tending to reduce the discomfort; and it can form the basic motivation which makes learning possible (as implied by the expression, "the burnt child shuns the flame"). As we shall see a little later on, an animal may *acquire new motives* when stimulated to action by pain.

Contact Comfort

A recent series of experimental studies with baby monkeys has shown that they have a strong drive to hug, press, and rub against the soft warm surfaces of objects having the approximate shape of their mothers. This drive was observed in monkeys who were reared apart from their mothers from birth onward. A "simulated mother" was made of a block of wood covered with terry cloth, and with a head containing eyes and nose of pilot-light jewels. The baby monkeys frequently sought out this object,

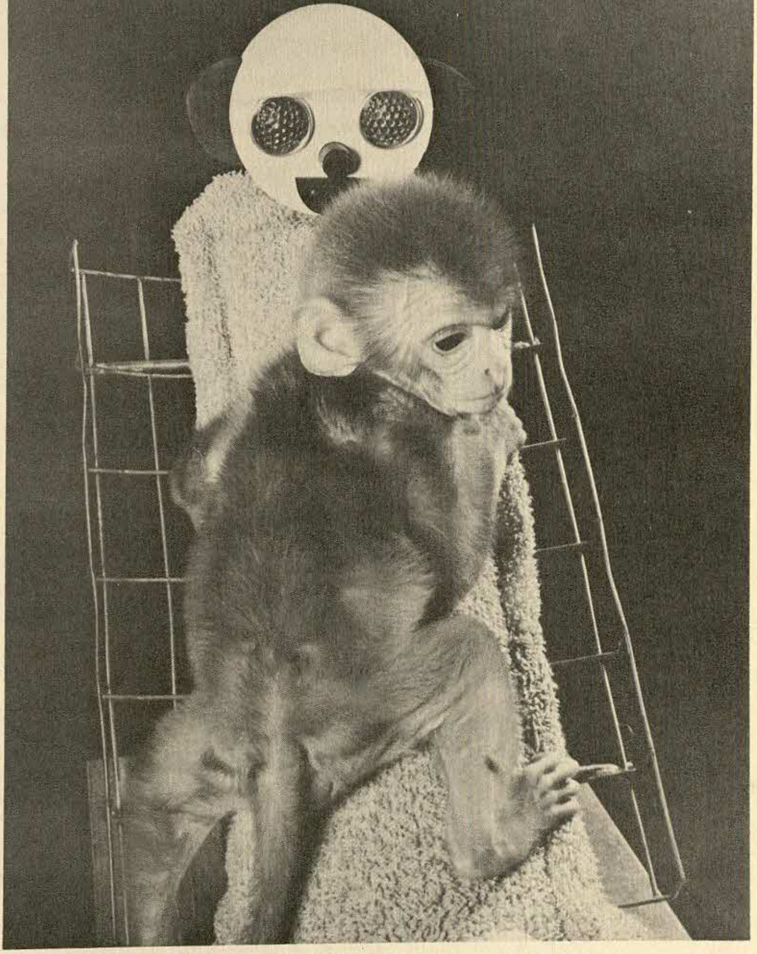


FIGURE 4.6. *A young monkey and its "simulated" mother. (Courtesy of Dr. Harry F. Harlow)*

hugged it and rubbed against it, and tended to use the object as "home base" for their play activities. This behavior occurred as strongly in monkeys who had been fed from a bottle by hand as in monkeys who had been fed at the simulated mother's "breast" (an attached rubber nipple). Thus it was shown that the "mother" was hugged and squeezed not because she was associated with satisfaction of the hunger drive, but because she provided *contact comfort.* See Figure 4.6. When a different kind of "simulated mother" was used, of the same size but made of wire mesh rather than soft terry cloth, the monkeys did not seek this object at all. In the normal monkey, an important drive is presumably satisfied by a rubbing contact with the skin of another monkey (usually, the mother). The existence of a similar drive in human beings appears highly probable.

Other Drives Based on Physiological Needs

Although perhaps less well understood, other physiological conditions of need can act as drives in animals and men. Among these are the need for breathing air, which may be called the *respiratory drive,* and the needs for emptying the bladder and colon, which may be termed *elimination drives.* Another need of some significance arises from stimulation in the cells of the muscles, presumably from some chemical state existing in these cells. This gives rise to a drive for activity or *muscular exercise.*

There are probably a number of additional specific needs, representing states of physiological homeostatic imbalance which originate other drives. For example, recent studies have shown that a curiosity drive may exist in monkeys and other animals.[6] Other studies show that human behavior is remarkably disrupted when an individual is deprived of normal kinds of stimulation. This is done by placing him in a specially constructed environment that removes sounds, sights, and even touch stimuli.[7] These findings suggest the possible existence of a basic need for sensory stimulation.

Drives and the Nervous System

Recent experimental studies of animals have demonstrated the importance for drives of a portion of the nervous system called the *hypothalamus,* which lies below and underneath the cortex.[8] The hypothalamus contains many tracts of nerve fibers which connect the ascending fibers of the spinal cord with the cortex; and others which connect cortical areas with descending motor fibers. It is now believed that this portion of the brain may be the locus of the central organization of drives.

Fine silver electrodes were implanted in a rat's brain so that they could deliver an electric shock of 0.5 second's duration. After recovery from surgery, the rat was placed in a box containing a lever which made an electric contact when pushed. When the circuit was closed so as to deliver an electric shock to the rat's brain, it was found that this stimulation behaved as a drive. In other words, the animal learned to press the lever, and continued to press it, in order to obtain the shock to his hypothalamus. The animal behaved much as he would if he were pressing the lever to obtain food (when hungry) or to obtain water (when thirsty). When the electrodes were placed in slightly different positions in the hypothalamus, it was found that shock stimulation could produce avoidance of the lever, rather than approach to it.

The suggestion from these studies is that the hypothalamus contains neural centers which are activated by physiological need states, and which in turn energize behavior. Furthermore, this activation may not be entirely

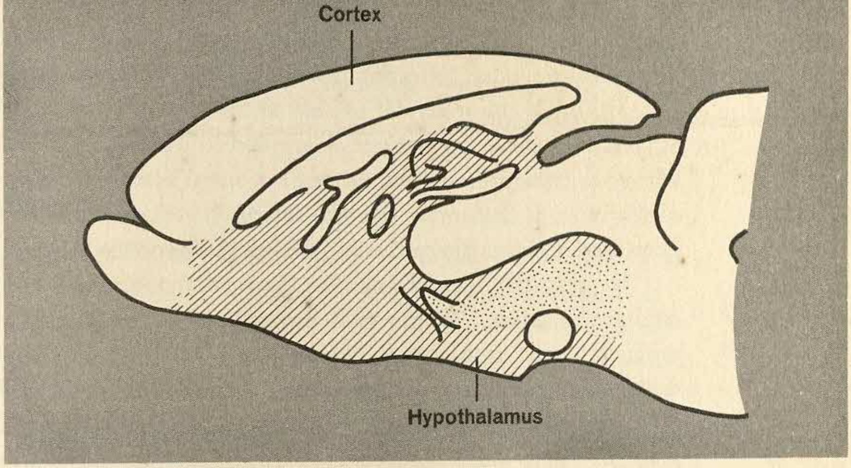


FIGURE 4.7. *Longitudinal section through the brain of a rat, showing the location of the hypothalamus. In most of this area (as well as in some neighboring areas), electrical self-stimulation produced approach behavior and continued lever-pressing. In the stippled area, electrical stimulation was found to cause avoidance. (After Olds, J., Self-stimulation of the brain,* Science, *1958, 127, 315-324)*

general in nature. It may be possible to find that there are different centers of the hypothalamus which control different drives. This is suggested by the fact that stimulation of one area makes the animal approach the lever while stimulation of another area makes him turn away.

Instincts and Drives

We often hear the term *instinct* applied to the needs for food, water, sex, etc. When used in this sense, instinct is obviously equivalent to the term *drive*. More often, we hear the term instinct used to mean more complex, highly stereotyped patterns of goal-directed behavior in particular animal species. Examples of these are nest-building by birds and migration by birds and fish.

For an activity to be called instinctive, it must meet two criteria. First, it must be found universally among all members of a species, and second, it must appear without opportunity to learn. As far as man is concerned, only the primary drives which we have described meet these criteria. Yet in everyday speech we frequently hear the term applied to behavior which does not meet either of these criteria. Thus, the preference for human beings to live in social groupings is sometimes referred to as the "herd instinct." We often hear the terms "parental instinct" and "fighting instinct." Such expressions make the unwarranted assumption that these are inborn human motives. One has only to examine different cultural patterns to refute the idea that these are instincts. For example, in one island culture, children are exchanged; in another, infanticide is traditional. Thus, although there is considerable evidence of a *maternal drive* or "instinct" in lower animals this does not qualify as one of the primary drives for humans. Such use of the term instinct as applied to humans is scientifically incorrect when we consider our two criteria. A more constructive approach has been to study such factors as the age at which certain motivational patterns appear, and to investigate the stimuli which influence these patterns.

Even in the case of animals, the term *instinct* may confuse rather than explain behavior. To say that birds fly north in the summer "because of instinct" explains nothing. What is needed is an explanation in terms of factors which control the behavior. Actually, it has been found that birds fly north in summer because of enlarged (and presumably more active) sex glands.[9] This was demonstrated experimentally by a comparison of two groups of snowbirds. One group was subjected to normal decreases in the duration of daylight from late fall to early winter. An experimental group was kept in an artificially illuminated aviary where, in contrast, the light cycle was increased each day. The latter birds sang in the aviary and when released flew north. The other group remained silent and when released remained in the vicinity. The birds in the experimental group developed enlarged sex glands, while the control group did not.

Studies have been made of the well-known instinct of migration in salmon.[10] Thus far, it appears that this is a complex matter which depends at various stages on (1) stimulation of receptors in the skin which are responsive to light, (2) need for oxygen, (3) preference for colder water, and (4) conditioning to certain odors. Thus, while the term *instinct* may be appropriate for such complex behavior in lower animals, much can be learned about the conditions and stimuli which affect these patterns. It is also true that many patterns which are thought of as unlearned turn out, under systematic scrutiny, to be largely learned.

ACQUIRED MOTIVES

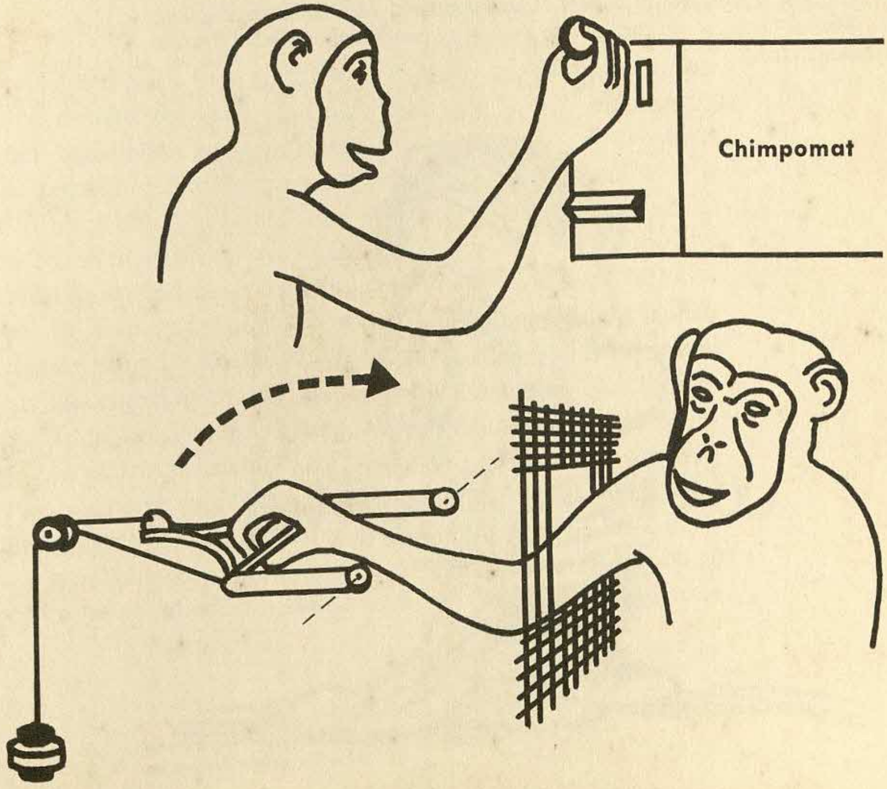
We have seen that human beings share with many lower animals certain fundamental drives based upon physiological needs. These primary drives provide the basic mechanism to energize human behavior. But, of course, they do not tell the whole story, nor the most important part of it, so far as human motives are concerned. For we know that human beings have a great variety of wants, desires, wishes, likes and dislikes. Where do these come from? Evidently, they are acquired. They are not built into the individual at birth, nor do they develop simply as a result of his growth, as does the sex drive. They result from the particular interactions an individual has with his environment; interactions of the sort which can, and usually do, cause learning to occur. Most human motives come into being in this way.

Learning New Motives

It is no great trick to acquire a new motive. An individual can learn a motive without being aware of it at all. When the environment is arranged properly for such learning, animals can acquire motives which are quite specific and unusual. For example, we are used to thinking of *making money* as an important and widely occurring human motive, presumably learned. But could an animal acquire such a motive? Indeed he could, and has.

Chimpanzees first were taught the habit of obtaining a grape or a raisin by inserting a poker chip in a vending machine called a Chimpomat. After some experience at this task, it was shown that the animals came to value the chips themselves. In other words, they had acquired motivation to obtain the poker chips, even though these could not always be used immediately to obtain food. The chimpanzees would now perform work to get the chips; they would pull a heavy weight in order to obtain a chip.

FIGURE 4.8. *A chimpanzee inserting a chip in the "Chimpomat" and pulling a weight to obtain a chip. (After Smith, K. U., and Smith, W. M.,* The behavior of man; an introduction to psychology. *New York: Holt, 1958)*



When they were prevented from using them immediately, the animals hoarded the poker chips, and spent them later to obtain food (see Figure 4.8).

The motivation acquired in this way was also quite specific. The chimpanzees were first taught to use a red chip to obtain food from the Chimpomat, a blue to obtain water, and a white one to get out of their cages and run around. Now different degrees of deprivation were put into effect for these fundamental drives. Then it was found that the animals would work hardest to obtain chips of the particular color that could be used to satisfy their greatest need. If they were more hungry than thirsty, they would pull a greater weight to get a red chip than they would to obtain a blue chip, and so on. Thus, in this relatively simple manner they *acquired new motives.* Poker chips became objects of value, like money, because they were associated in a learning situation with the satisfaction of a basic drive. There are many other similar experiments which demonstrate how originally "neutral" objects and situations become goals. The principle is that the *stimuli which regularly precede the satisfaction of a primary need may themselves become learned goals.*

The young child undoubtedly acquires new motives in much the same way. The individual (usually, his mother) who feeds the child and comforts him soon comes to be a loved and desired object because of her association with the satisfaction of fundamental needs. Very soon the infant cries to be picked up even when he is not hungry. Or an old blanket which

URE 4.9. *Linus and his blanket. Once associated with bodily satisfaction,* *blanket becomes a learned goal in itself. (By permission of United Feature* *dicate, Inc.)*

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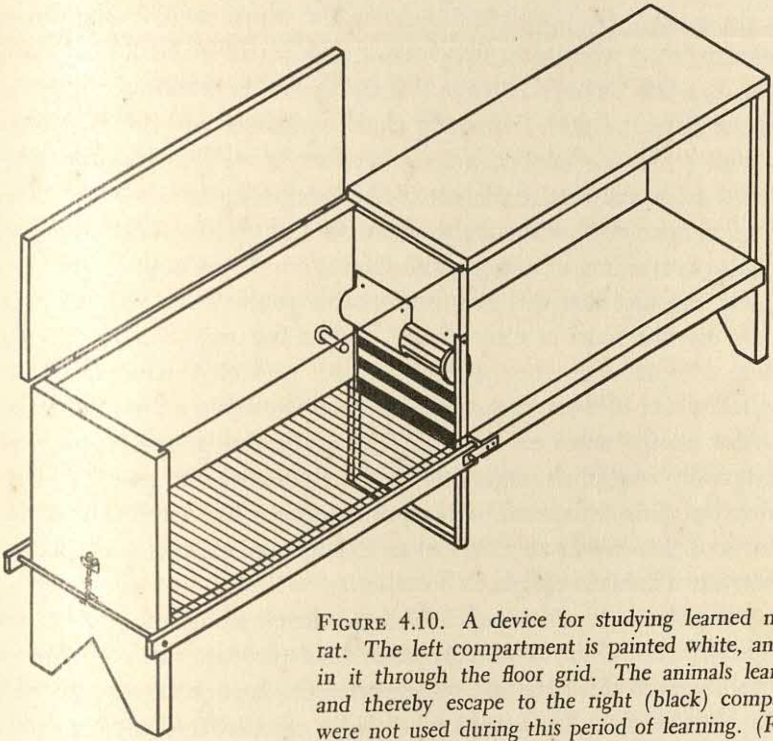


FIGURE 4.10. *A device for studying learned motivation (fear) in the white rat. The left compartment is painted white, and electric shocks are delivered in it through the floor grid. The animals learned to spin the small wheel and thereby escape to the right (black) compartment, even though shocks were not used during this period of learning. (From Miller, N. E., Studies of fear as an acquirable drive: I. Fear as motivation and fear-reduction as reinforcement in the learning of new responses,* J. exp. Psychol., *1948, 38, 89-101)*

is originally associated with the satisfaction of bodily needs and comforts may come to be desired for itself, and may remain a "loved" object long after the original association has terminated (see Figure 4.9). Many adult motivational patterns probably develop in this way, although of course it is more difficult to trace them. Aggressive or submissive tendencies in adults may have their foundations in the way early primary needs are satisfied by the parents. We see around us every day, particularly in advertising campaigns, attempts to have us acquire new motives through association with other need-reducing stimuli. We are frequently told that increased sexual attractiveness is associated with the use of certain lotions, cigarettes, or other products. To a considerable extent, the misnamed phenomenon of "brainwashing" is a dramatic example of how entire motivational patterns of adults can be changed over time through the subtle manipulation of propaganda in relation to the satisfaction of primary needs.

ACQUIRING FEARS. Negative motivation to previously neutral objects or situations may also be acquired in a similar manner. There is considerable evidence that fears, hates, and other avoidance patterns are learned. Again, animals have been used to demonstrate this kind of occurrence in order to test its basic nature. In a typical experiment, a white rat is placed in a compartment painted white, and stands on a grid, as shown in Figure 4.10. Pain is used as a fundamental drive in this study, and is aroused by electric shocks delivered to the grid. Since the shock was invariably delivered in the right-hand (white) chamber, after a number of such experiences the rats exhibited a learned motive of *fear* of this compartment. When placed in the white compartment without the shock, they showed many symptoms of fear such as crouching, urination, and defecation. Even more important, however, was the fact that this acquired motive could itself be used as a basis for the establishment of a new habit. When the animals were placed in the white compartment, they readily learned, without further shock, to spin the small wheel between compartments, and thus open a door to escape into the black compartment on the left. This is another example, then, of how an originally neutral situation (the white chamber) can acquire motivating value by being associated with a primary drive like pain. The situation can arouse this newly acquired motive, fear, and this in turn can be used to motivate a habit of escape.

One of the classic experiments showed the development of an acquired fear in a child.[11] The child, Albert, was first shown a white rat. He showed no fear. As he reached for the rat, the experimenter struck an iron bar just behind the child's head. The sound produced a startled fear reaction, and later produced crying. Soon Albert showed fear reactions to the white rat alone. He also appeared afraid of rabbits and other furry, inanimate objects. This study is in many respects similar to the classical animal conditioned-response experiments to be described in Chapter 6. It also demonstrates the importance of the principle of *generalization* in learning. Thus, the child's fear response became connected not only to the original object, the white rat, but also to other objects which resembled the rat in some degree.

Very often we have vague fears as adults, often called *anxieties,* which we cannot explain. In some extreme cases these fears may be quite specific, such as the fear of small enclosures, of high places or of mice. Extreme fears of this sort are called *phobias.* Such fears are often the result of forgotten childhood experiences similar to Albert's. When these concerns reach serious proportions, the aid of a therapist may be sought. One of his basic functions in these instances is to discover the original painful stimuli which account for the acquired negative motives.

Acquiring Social Motives. A large portion of man's motivated behavior cannot be explained in terms of association with primary motives or in terms of simple learning and generalization. It is true that much of what we call social behavior is learned in the course of satisfying primary drives. However, once social motives are acquired, they themselves become the basis for further learning. Thus, the child's acquired love for his mother is a result of her role in satisfying early primary needs. But mother-love itself is a very powerful motivational force in our culture. The mother, in this sense, becomes an incentive whose presence satisfies a social need much as food reduces hunger. Moreover, social motives often take precedence over primary drives. A man may starve rather than beg for food. Another will give up sex for religious motives. The rewarding of social motives constitutes one of the primary ways in which man's behavior is regulated.

Some Social Motives

Now that we have considered the ways in which motives may be acquired, we may examine some of the more important social motives. It is impossible to present a complete list, because many are quite specific and others vary from culture to culture. It is also true that behavior toward a specific goal may be energized by multiple needs operating in combination. Consider for a moment the varieties of motivational pressures (positive and negative) involved in seeking a college degree!

We shall also see that the same social motives may lead to a variety of different goal responses. For example, although the hunger need can be reduced only by food, the need for attention can be reduced by competition, cooperation, or other forms of social behavior.

We shall consider here only a few of the more common social motives in our culture.

AFFILIATIVE NEEDS. In modern society most people have strong motives to live together, play together, and work together. This motivation may show itself in several forms. Early in life it is evident in the dependency of the child on the parents. But in adult life this need persists. Man feels a real deprivation when he cannot associate with others. It is noteworthy that one of the most extreme punishments imposed in our penal system consists in thwarting this need through the device of solitary confinement.

The potency of this need for affiliation with other people is seen in many industrial work situations. Studies show, for example, that when workers are paid according to the amount they produce they may still hold back on their production. A famous study at the Western Electric Company showed that one reason for the failure of such a "piece rate" plan was the affiliation need.[12] The person who produced more than a certain amount was called a "rate buster" and was shunned by his fellow workers. Individuals preferred to earn less rather than to risk discrimination. Another example of this need is exhibited in the tendency of workers to continue working beyond retirement age. Loss of contact with friends and associates is an important problem for older people. Programs which provide outlets for this need, in the form of clubs and other group activities, have proven extremely valuable for the maintenance of mental health in older people.

Often industrial job designs overlook the importance of the affiliative need. Many production layouts, working rules and practices that limit social interactions are undesirable. For example, in a large utility company, one operation was set up with a hundred girls working in an open room sorting bills as they came in.[13] The job is basically a tedious and exacting one. Turnover, absenteeism, and errors among the girls were high. Then the layout was changed to provide a series of ten rooms, with ten girls to a room. Although the routine of the work remained the same, the absenteeism, turnover, and errors were markedly reduced. The girls formed closer contacts with each other and now felt part of a group. When slightly ill with a cold, for example, a girl might formerly have stayed at home ("They'll never miss me"). Now she would make the extra effort "not to let the group down."

In Chapter 10, "Social Behavior," we shall be discussing additional examples of the functioning of the need for affiliation in industrial and other situations.

STATUS NEEDS. Another set of acquired needs are those of achieving personal power, prestige, or status in one's group. This need to feel oneself a person of consequence is sometimes called the *ego need.* The need for status is evident in the many official and unofficial *status symbols* in human societies. Titles and rank designations among business people, college professors, church officials, fraternal functionaries, and military officers are obvious examples. Unofficial symbols in business firms may include the size of one's desk, whether one has a rug on the floor, or even the possession of a key to a particular washroom. Men may choose lower-paying white collar jobs over higher-paying blue collar jobs for status reasons. A change in title may give some men more satisfaction than a raise in pay.

Status differences are common among many animal groups. A herd of cows forms a status order according to which they return to the barn. Barnyard hens establish a "pecking order," in which one hen has pecking rights over the others. Hens of lower rank may peck those beneath them but not those above, while the least dominant may be pecked by all the rest. (Hence, the root of the term "hen-pecked" and its obvious status implications.)

The motive of *face-saving* is an important everyday manifestation of the ego need. This need is much more important in certain Asian cultures, but it is also strong in ours. A man may quit a good job rather than apologize to his boss. Labor-management disputes continue for weeks and are settled on the basis of an amount which may be as little as half a cent an hour. Often, the reason for this is that neither side is willing to make the last concession, since this would be considered a loss in status. Thus, the final cent of an original 50-cent difference may have to be split into two equal parts!

When one says "I told you so," he is gaining prestige at someone else's expense. To scold a child in front of visitors represents a failure to comprehend the strength of the child's ego need. The adult who tries this on another adult invariably incurs a strong reaction of resentment.

Plant operations which are ideally designed from engineering standpoints sometimes fail to consider the status needs of the individual. Assembly line operations, automation, and task specialization are all industrial trends which remove from the individual the opportunity to use many of his skills. Moreover, the individual tends to feel that he is easily replaced, since the skills required of him are so menial that anyone can do the job. The consequences of such trends are obviously some loss in feelings of status and self-esteem, unless other ways can be found to satisfy these needs.

In particular circumstances an assembly line operation, with each individual performing one operation in the assembly, is not necessarily most efficient for industrial operations. In one study, production records for an assembly line operation were compared with a new job layout arrangement which provided a separate work station for each individual. In the latter arrangement, each worker was responsible for making the complete assembly. The results are shown in Figure 4.11. It is apparent that errors were markedly reduced. Production remained at the same level or went higher. In addition the morale of the workers increased. This does not mean that assembly lines are invariably inferior to other kinds of industrial operation. But in some instances, giving the worker control over his output, so that he can use more of his skills and consequently derive greater ego-need satisfaction, may have beneficial results for the worker and for his productiveness.

Another form of status need is represented by the need to achieve success. People differ markedly in this *need to achieve*. These differences show themselves in how much effort people exert on almost any competitive task. This accounts to some extent for the fact that people with lower degrees of skill often surpass others more talented. Just as a hungry man's thoughts are dominated by food, a thirsty man's thoughts by water, an individual with a high achievement need may be similarly driven. It has been demonstrated that people with a strong need for achievement read competition and success into ambiguous pictures about which they are asked to write stories.[14]

LEVEL OF ASPIRATION. Level of aspiration refers to the goal level an

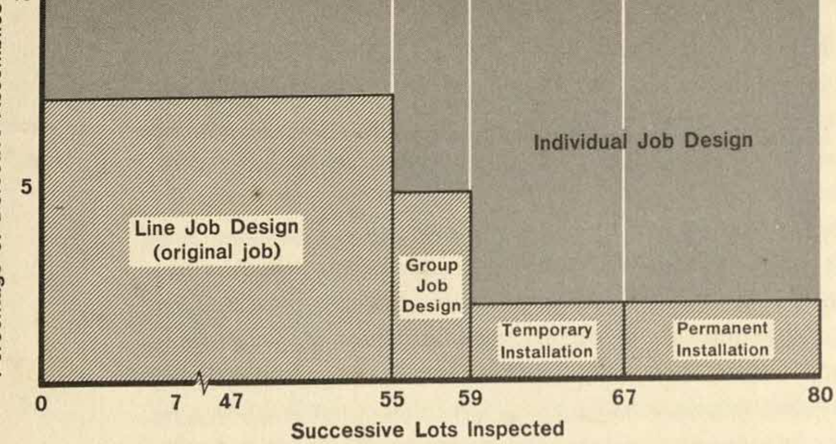


FIGURE 4.11. *Status needs and the design of jobs. In the Line Job design workers were stationed by an assembly line and each worker performed one of the nine operations required in the assembly of the product. In the Group Job design, four workers assembled the product in a group. In the Individual Job design each individual performed all but one of the operations in the assembly, giving the individual employee more complete control over productivity and quality of the finished product. The average decrease in defective assemblies is shown for each job design. (Adapted from Marks, A. R., An investigation of modifications of job design in an industrial situation and their effects on some measures of economic productivity. Unpublished Ph.D. dissertation. Berkeley: Univ. of California, 1954)*

individual sets for himself on a particular task. Experimental findings show a definite relationship between a person's previous performances and his aspirations about future performance.[15] Failure tends to make one lower his aspiration level; success tends to make a person raise it a little. This, of course, is obvious and normal. However, these results emphasize the importance of providing "success experiences" for the purpose of maintaining high motivation, whether one is teaching children or training industrial workers. In industry, a production goal which too far exceeds the skills of the individual worker may result in depressing performance rather than raising it.

One of the sad consequences of an economic depression is the sense of failure experienced by large segments of the population. Such experiences are likely to result in lowered levels of aspiration, with important consequences persisting for years afterward in our society. This is consistent with the finding of lower levels of aspiration in certain minority groups (e.g., Negroes, Mexicans) who tend to be paid lower wages, are the first to be laid off, and experience other kinds of failure.

We see the consequences of unrealistic levels of aspiration in some college students. In our culture, professional careers such as those of physician or lawyer are highly esteemed. Parents frequently set such goals for their children. It is not uncommon to find average or below average students experiencing repeated failure (grades which do not qualify for professional schools) throughout their college years. Adaptive behavior, on the part of parents and students, would be to lower the level of aspiration. Adequate counseling of both parents and students at an early stage can do much to solve such problems.

ACQUISITION NEEDS. Acquisitiveness is a learned motive which is not universal among men. It is known that large numbers of people show little concern with the acquisition of wealth. Among certain South Sea cultures, all property is held in common. The fish catch, for example, is divided up according to the size of each man's family and not according to each man's efforts. In our own culture, the desire to accumulate wealth often seems to be an expression of status needs.

In any case, this need exists in large numbers of people and has received considerable study in its own right. It is of interest that acquisitive or hoarding behavior is found in lower animals, and that in many it appears to be an inborn need. Squirrels store up nuts in winter even if they have been in captivity all their lives. In white rats, such behavior has been shown to be related to early frustration of the hunger need. For example, when rats which were kept hungry as infants were allowed to regain their weight in adulthood they continued to hoard more than other rats. Similar food hoarding occurred among children in war areas when food became more readily available. In these children, the food apparently became a learned incentive which was valued in its own right rather than for its hunger-reducing value alone. Similarly, some people have been known to deprive themselves of physical comforts to satisfy their acquisitive needs for possessions or money. Such miserly behavior may often be understood in terms of childhood deprivations and consequent acquired motives of acquisition.

THE EFFECTIVENESS OF INCENTIVES

Our discussion has been focused on the drives and acquired motives that impel people to behave in certain ways. As we have pointed out, the total sequence of motivation includes the need state itself, the kinds of behavior motivated by this state, and the goal response made to reduce the need. And we have seen that in acquired motives especially, a variety of goal responses may satisfy the same need. In this section, we will look at the incentive end of the motivation sequence.

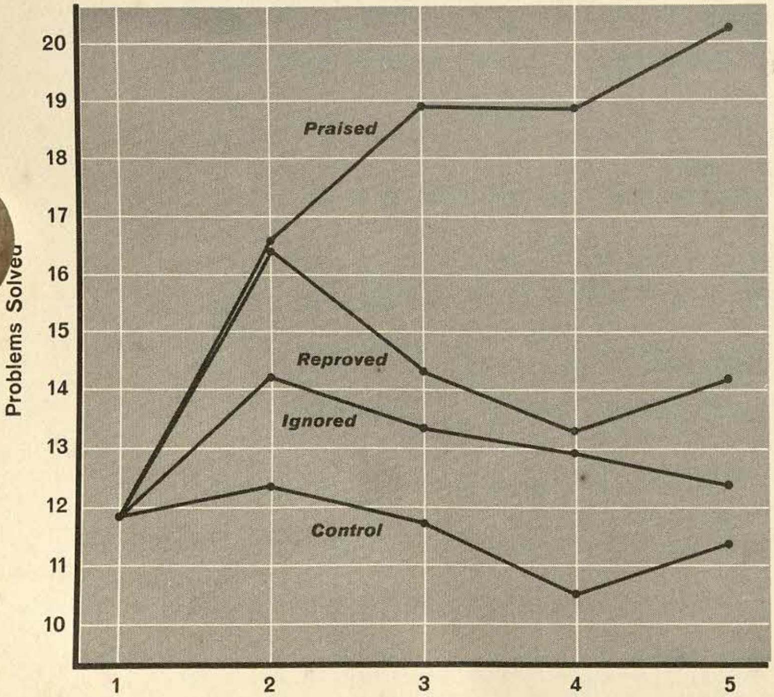
Incentives are often used to control the behavior of other people. Parents are continually manipulating incentives in order to control and direct the behavior of their children. Employers use incentives to get people to work in desirable directions. Political parties use incentives to guide voting behavior. What is the scientific evidence on the effectiveness of various kinds of incentives?

Praise and Reproof

Some of the most frequently manipulated incentives may be classed as verbal rewards or punishments. Much of what we do is done in the hope of receiving praise and avoiding reproof. The manipulation of these incentives by others is directed largely at our status and ego motives.

Experiments comparing praise and reproof usually show praise to be more effective. Figure 4.12 presents the results of a study of four groups of school children who performed tasks of addition at intervals over a five-day period. A *control* group, in a separate room, had no comment made on their performance. In the *praised* group, children were called up to the front of the room and complimented and encouraged. Students in the *reproved* group were also called up, but reprimanded for poor work and carelessness. The fourth group, the *ignored* group, heard the other comments but were not called up. The results show that, although the groups were equivalent initially, both the praised and reproved groups showed

FIGURE 4.12. *Number of addition problems solved by children given different verbal incentives. (Data from Hurlock, E. B., An evaluation of certain incentives used in school work, J. educ. Psychol., 1925, 16, 145-159)*



increases on the second day, as compared with the ignored and control groups. Following this, the praised group continued to improve while the reproved group did not.

Table 4.1 summarizes the results of various studies carried out with college students, with respect to whether the results of a particular method of praise or reproof were better, no different, or poorer than other methods. This table indicates that praise for past efforts is superior to the many forms of disapproval attempted. Only one method of disapproval more often facilitates rather than impairs performance, namely, private reprimand. Public ridicule and sarcasm may actually be viewed as increasing the ego need, rather than satisfying it. The fact that public forms of disapproval are most harmful is consistent with this interpretation.

TABLE 4.1
EFFECTIVENESS OF POSITIVE AND NEGATIVE INCENTIVES

INCENTIVE	PERCENTAGE SHOWING		
	Better Results	*Same Results*	*Poorer Results*
Public praise	87.5	12.0	0.5
Private reprimand	66.3	23.0	10.7
Public reprimand	34.7	26.7	38.7
Private ridicule	32.5	33.0	34.5
Public ridicule	17.0	35.7	47.3
Private sarcasm	27.9	27.5	44.7
Public sarcasm	11.9	23.0	65.1

(Data from Moore, H., *Psychology for business and industry.* New York: McGraw-Hill, 1939.)

Punishment

Punishment has been one of the most widely used devices for controlling behavior, from ancient to modern times. (Of course, verbal reproof is a form of punishment, but we are concerned here with more extreme forms). "Spare the rod and spoil the child" is a well-respected epigram. Traffic violators are fined and jailed to motivate them to conform in the future. War leaders are executed to motivate others to prevent wars. What is the evidence on the effectiveness of punishment as an incentive?

The results of studies on the effects of punishment are not as consistent as those dealing with reward. Generally, evidence from experiments indicates that punishment is less effective than reward. The reason is probably that reward directly strengthens the rewarded behavior, while punishment works only indirectly. Thus, the rewarding of behavior leads to later repetition of this behavior. A response that is punished is simply blocked, but the punishment does not weaken the tendency of this response to occur at at later time. This may be why the results of punishment are found to be less permanent than the results of reward.

Let us examine how punishment is usually applied, in order to understand some of these results. First of all, the individual responds to a stimulus in some manner which we want not to recur. What is desired is the destruction of a previously acquired habit. If this habit is well learned, we cannot expect to change it with one or two applications of punishment. Thus, the child who has had frequent recourse to the candy jar will not have this response weakened much by one or two scoldings, simply because the habit is too strong. We usually give up before a detectable change is observed.

Another reason why punishment often does not work is the occurrence of a delay between the undesirable response and the application of punishment. In the above example, the missing candy may be noticed several hours after the child has taken it and the punishment administered at this time. But this event contrasts with the immediate reward the child gets in eating the candy. If such a sequence is repeated day after day, the response will be strengthened every day faster than the delayed punishment can weaken it. This kind of mechanism is probably involved in the application of punishment to antisocial behavior. The burglar receives immediate reward from the money he steals, while the delayed punishment is his prison sentence.

A further characteristic of punishment as a negative incentive is that new habits may be established which are equally undesirable. The child who is made to sit in the corner for talking in class may eventually break this habit, but he may also learn to hate school.

We have mentioned some of the reasons why punishment may not be effective or, at best, may often be unpredictable in its effects. But we all know that in many cases punishment *is* effective. For example, an individual who receives a speeding ticket driving through a small town is likely to drive more slowly the next time through. In cases like this, punishment seems to operate in a manner similar to that involved in learning to avoid a painful stimulus. The stimuli associated with the painful consequences also produce avoidance responses (e.g., the shocked rat avoids the white compartment, the burnt child avoids the stove, hot or cold). We may say that punishment works not by weakening the original habit but by substituting other responses to the same stimuli. It is worthy of note that in these instances the "punishing stimuli" (the policeman, the white compartment, the stove) are present immediately after the "undesirable" behavior. As we have already seen, an acquired motivation of fear may become strongly attached to such stimuli, which in turn may strengthen habits of avoidance.

Punishment also may have an *informative* function, which redirects the individual's behavior. Thus, a low grade on an exam paper is punishing, but it will not in itself facilitate learning. However, it can energize behavior which, if correct, can later be rewarded. The informative role of punishment is a useful one for parents. Firm discipline, administered promptly and consistently, but not harshly, is a good policy. Punishment in this setting informs the child, who is "testing the limits" of what is permitted. Inconsistent, postponed, or vague punishment probably is not going to be effective (for example, "Wait till daddy comes home").

Money

Industrial concerns often make the assumption that money is the incentive of most value to their employees. Money is involved in the satisfaction of primary needs like hunger, as well as of acquired needs such as status. However, a great number of studies have been made on what workers want most, and these almost never show pay at the top of the list. Usually, factors such as security, recognition, and good relations with supervisors turn out to be valued most highly. Nevertheless, the amount of pay always appears as one of the main incentives. The evidence shows that high pay is one of the strongest attractions to a job applicant, but is somewhat less effective as an incentive for keeping him on the job.

Amount of pay is frequently manipulated in various wage-incentive systems. Thus, workers may receive pay on a straight time basis, on piece-rates, in accordance with formula rates based on production above a specified standard, by bonus systems, and by profit-sharing. In a sense, the straight time method is an incentive only to attendance and a minimum productivity level, while the other methods assume a relationship between how much a man will work and how much he is paid. Little is known about the comparative effectiveness of these various incentive plans, and there is much controversy about them. In any case, such plans are often based on oversimplified notions of human motivation. One may point, for example, to the manager who works overtime or takes work home, even though he is paid on an hourly basis. Or, one can easily find a worker who is paid on a piece-rate basis, who does not work hard and earns less than he might earn, and who then goes home and works hard on his hobby. Clearly, other factors besides money may motivate workers.

Figure 4.13 shows a case in which a pay incentive plan did work, as well as an instance in which the same plan did not work. The conditions under which such plans work appear to depend on other factors besides the amount of money. For one thing, such incentives may be regarded with

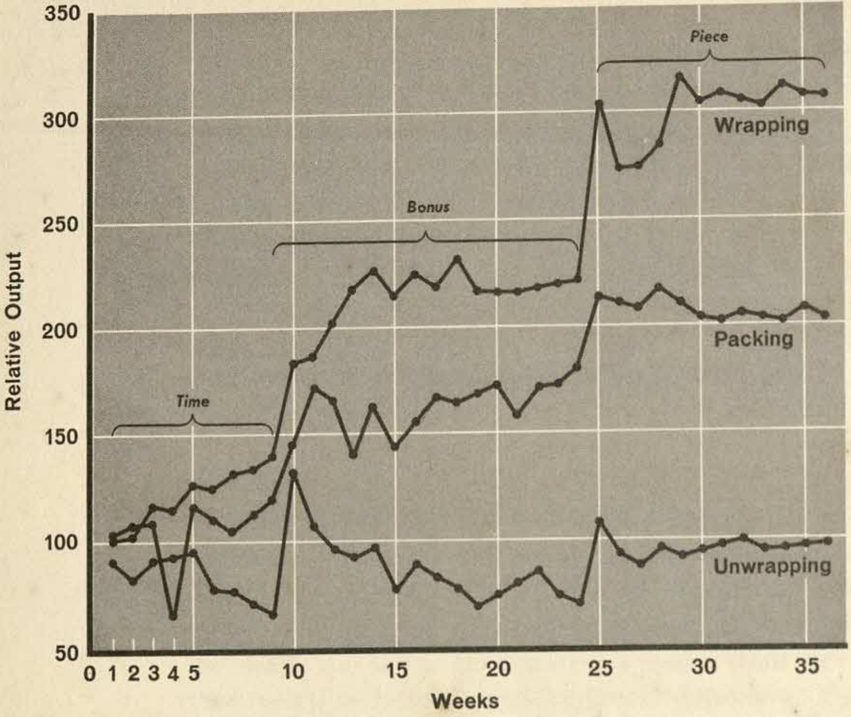


FIGURE 4.13. *Effects of pay incentives. In general, the bonus incentive produced an increase in production, and the piece-rate incentive produced an even higher level. However, for the unwrapping job, despite an early spurt at the start of the bonus plan, these financial incentives were not effective. (After Wyatt, S.,* Incentives in repetitive work. *Industrial Health Research Board, No. 69, London: His Majesty's Stationery Office, 1934)*

suspicion: workers may fear that with a speed-up fewer workers will be needed, or that higher standards will later be set. As we shall see in Chapter 10, group pressures often limit production no matter what the pay incentive is. Such plans are most likely to work when the workers participate in setting the new production standards, and when they have intrinsic interest in the work itself.

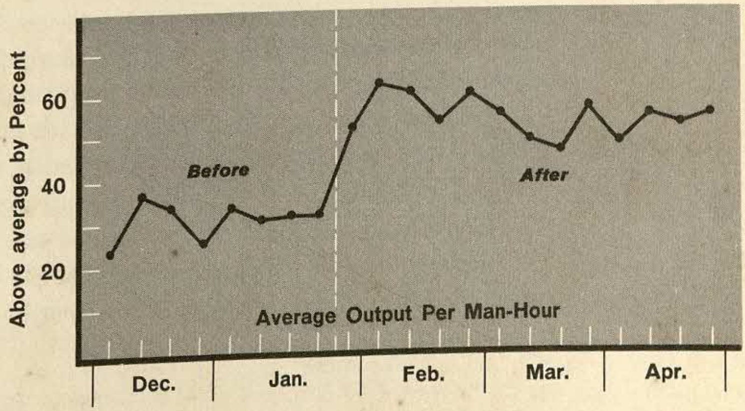
Participation

Participation appears to be one of the most effective incentives in motivating behavior. It may be used as a goal for satisfying both the status need and the affiliation need. A number of studies have shown that behavior may be more effectively changed by using participation as an incentive than by employing persuasion. For example, during World War II an attempt was made to change food habits so that meat would be used more efficiently during the shortage.[16] A skilled nutritionist lectured on and discussed with one group of women the nutritional value of heart, brains, kidneys, etc., and ways of preparing them. A follow-up investigation showed that only 3 percent of the group had tried these foods. In another group, a discussion leader who knew nothing about nutrition got the women to discuss the problem themselves. The time spent and the problems discussed were the same as those of the lecture, but the individuals participated in the decisions of the group. A follow-up study of this group showed that 32 percent of the women had tried the previously shunned foods.

Similar studies have been carried out to get mothers to follow proper baby-feeding procedures.[17] In this case individual consultation was compared with group participation. The finding was that the "personal attention" method was less than half as effective as group participation.

There is increasing use of participation in the setting of goals as an incentive in industry. Figure 4.14 shows the results of one study in which girls were allowed to participate in setting new production standards. The girls were paid on a piece-rate basis. During three weekly meetings, the group discussed setting new goals. The goal decided upon in the first meeting was to get production up to 84 units per hour within five days. Sixty units had been standard up to this time, with 75 the assumed ceiling. Nevertheless the goal was reached, and at the next meeting the goal was set at 95. This figure was not reached, and the group decided to hold the goal at 90. The production was actually stabilized around 87 units per hour. It is of interest that the pay incentive was not responsible for the increase, since the pay method remained the same. Potentially, the girls could have been earning more before they were allowed to participate.

FIGURE 4.14. *The effects of participation on productivity. Workers were allowed to participate in setting the production goal. After deciding upon a rate they thought was feasible, there was a sharp increase in output which persisted despite the fact that the pay rate was not changed. This effect was maintained even though these groups were already above the plant average. (From Woodworth, R. S., and Marquis, D. G.,* Psychology *(5th Ed.). New York: Holt, 1957. After Bavelas)*



Knowledge of Progress

Knowledge of progress, or knowledge of results, is an important factor in the learning of new habits and skills, which we shall discuss in Chapter 6. Without knowledge of results, little learning occurs. However, here we are interested in noting that knowledge of progress functions as an incentive for the performance of previously learned skills. Even after a task is well learned, knowledge of results facilitates performance. In one study, the performances of groups of college students were measured on tasks of arithmetic, letter cancellation, and symbol substitution.[18] A group that was shown its results improved more than a control group on each type of problem. Then the group which had been given knowledge of its progress was kept ignorant of its results, while the original group was now shown its performance progress. When this was done, the original control group excelled the other group. Thus, knowledge of progress has a pronounced rewarding effect.

In industry and military situations, one frequently sees progress curves used as incentives. In training situations, the instructor may display learning curves for each individual as a motivating device. Progress charts are often used, too, as incentives in public fund-raising campaigns.

Competition

In our society, competition is an important incentive. So too is cooperation. It is often said that competition is mainly responsible for America's industrial position. Yet businessmen are continually trying to reduce competition in one way or another, and may even form cooperative associations to promote common interests. So the question of whether competition or cooperation is the more effective incentive is not a simple one. Actually, the problem is to find the conditions under which both competition and cooperation function effectively as incentives. When people compete with each other for the satisfaction of winning, the person who wins gains status and satisfies his need to achieve. But at the same time, the loser loses status and is prevented from satisfying his need to achieve. Thus there is often the question of whether the *net effect* of competition facilitates behavior more than does the incentive to cooperate.

We know that cooperative behavior can be learned as a replacement for competitive behavior. In one experiment with animals, a pellet was dropped into a cage containing three hungry rats.[19] At first they fought over it. What usually happened was that while two were fighting, the third rat ran off with the pellet and ate it. Some of the groups learned the solution of sitting quietly while each rat nibbled at a corner of the pellet. Figure

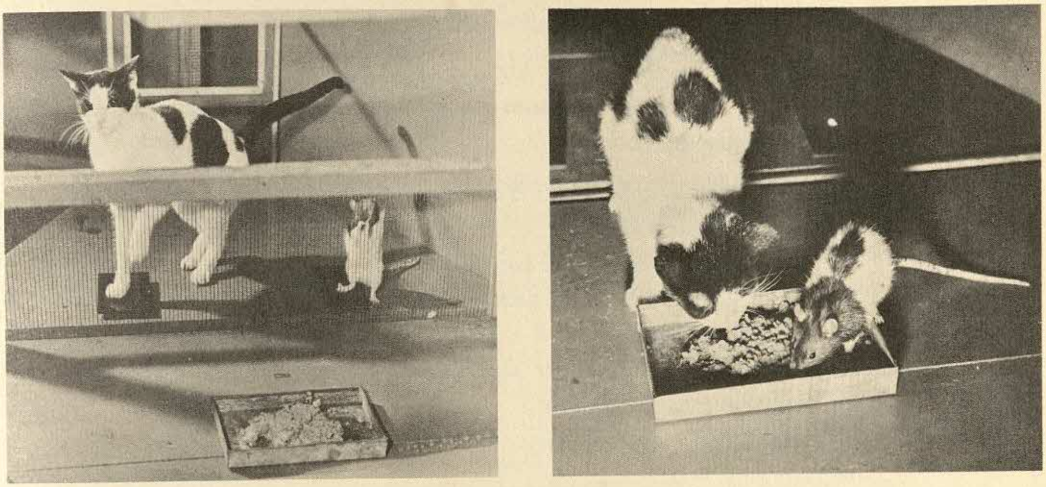


Figure 4.15. *Learning cooperative responses. In order for either the cat or the rat to get food, both were required to press separate metal plates simultaneously. The normally hostile animals learned a complex sequence of such cooperative responses. (Courtesy Dr. Loh Seng Tsai)*

4.15 shows another example of learned cooperative behavior. These instances suggest that if cooperative behavior is more rewarding than competitive behavior it is readily learned.

But what if the *same* rewards are involved for both competitive and cooperative behavior? In other words, what is the incentive value of competition itself? In one experiment, 814 children were told they were being tested to find out who were the fastest adders in the school.[20] In the control condition, the students "just practiced." In the competitive condition they were told that the fastest adders would get prizes. In the cooperative condition, the children were told that their scores for the class would be averaged and would count toward a class prize.

The performances of both the latter groups were superior to that obtained in the "no incentive" condition. Individual competition, however, was found to be more effective as an incentive than cooperation.

Other studies have confirmed the finding that competition between groups is not as effective as individual competition. The reason seems to be that when responsibility is divided, the status needs of individuals are not as directly affected. On the other hand, group competition has been utilized with considerable effectiveness when groups are formed into teams in such a way that individual status is a function of his contribution to the group. If this is done, social pressure on the individual tends to be the vehicle for applying the incentive. The concept of "morale" implies a feeling that group goals and individual goals coincide. What we often have in team performance is a combination of cooperative ("don't let our team down") and competitive ("beat the other team") incentives.

Hierarchy of Motives

It is often assumed that if the primary needs are satisfied, there is less need for satisfaction of the acquired "higher-order needs." Similarly, it is sometimes said that the satisfaction of social needs can substitute for satisfaction of primary physical needs. In industry, for example, when jobs are plentiful and wages high, it may seem that relatively less attention need be paid to the satisfaction of social needs. On the other hand, when wages are low and jobs are insecure, it is sometimes assumed that more attention to social needs can compensate. The evidence does not bear out these assumptions.

When a threat of deprivation to the primary needs occurs, their satisfaction becomes compelling and they take precedence over other needs. The hungry infant does not stop crying no matter what other kinds of ego-satisfying attention he is given. The seaman adrift in a lifeboat is motivated by thirst and hunger. He cares little for the companionship of his friends or their view of his status at that time. When he is rescued and is no longer thirsty and hungry, his affiliative, status, and achievement needs become dominant again. Similarly, in industrial situations, social needs assume increasing importance in times of security and full employment.

FRUSTRATION AND CONFLICT OF MOTIVES

As we have said previously, motives rarely operate singly; most often they operate in combination. Fortunately, most of the time one motive predominates and our behavior is energized toward reducing the strongest need. We may enjoy a pleasant discussion with friends (satisfying an affiliative need) before lunch. As we get hungry, we wish someone would suggest lunch, but we do not wish to break up the group. We have a momentary conflict about what to do. When the hunger need becomes sufficiently stronger than the affiliative need, we break away and go to lunch.

Unfortunately, many situations arise where the satisfaction of one motive results in the *frustration* of another. This is what is called a *conflict* situation. Until the person moves to satisfy one motive or the other, he usually has the experience of making a difficult decision. If the conflicting motives are strong, and if they are about equal in strength, there may be other behavioral consequences which we shall describe below.

Types of Conflict

There are three basic types of conflict. *Approach-approach* conflict is a conflict between two (or more) positive incentives each of which satisfies a need. We have such a conflict of primary drives if we are both sleepy and hungry. A common example in college occurs when two attractive courses are listed at the same hour. The jackass who starved halfway between two bales of hay reacted to such a conflict in a nonadaptive manner. Ordinarily such conflicts are not difficult to resolve. After a period of indecision, one chooses one goal and forgets the other one.

Approach-avoidance conflicts occur when a single goal has both positive and negative incentive properties. The child wants to pet the dog, but is afraid of it. A man wants a pay raise, but is afraid to risk a refusal by his boss and thus "lose face." The commonly occurring conflicts between the sex drive and social or religious values are of this type. The normal reaction to this type of conflict is indecision and compromise.

Avoidance-avoidance conflicts are those in which the individual has to choose between two negative incentives. The individual must choose the lesser of two evils. The army private must clean the latrine or face punishment, the man must take an unpleasant job or remain unemployed. Two characteristic reactions to this type of conflict are *vacillation* and *escape*. As a person approaches a negative goal he finds it increasingly repelling. Consequently, he turns in the opposite direction. This *vacillation* is repeated until a decision is made. Escape behavior is shown in the soldier going AWOL, the child running away from home, or the student dropping out of college when faced with a choice between two negative incentives. The adult or child may escape in other ways, by using concepts to "imagine" a solution, or by engaging in daydreaming or in fantasy.

Other Types of Frustration

While conflict is one of the main ways motives may be frustrated, there are other forms of frustration. Frustration occurs whenever goals are not achieved and motives go unsatisfied. This implies some block in the motivational sequence. In addition to those blocks resulting from conflict, there are environmental and personal obstacles. Examples of environmental obstacles are the following: the man alone on the desert island has his sex motive frustrated; the child cannot reach the candy jar or stay up late; the research scientist cannot get funds for his project. Personal obstacles involve inadequacies within the individual in relation to his goals. A short boy cannot make the basketball team; the C student does not get into medical school.

Reactions to Frustration

We shall review here some of the most common of the many ways that people have of dealing with frustration, whether it be due to conflict or environmental or personal obstacles. In general, these ways represent learned habitual responses to frustrations, acquired according to the principles of learning described in other chapters. If a particular response eliminates the frustration, this event acts as a reward, and the individual is apt to repeat the response in future frustrating situations. For example, if a child throws a temper tantrum when deprived of candy, the mother may give in. The child will soon learn this method of coping with this frustration, since this behavior has been rewarded.

Some habits are learned which are more adaptive in our society than others. For example, one method of dealing with frustrations is *compensation*, which is turning one's attention and energies away from the original goal and substituting another from which satisfaction can be gained. The frail boy who can't make the football team may have his need for recognition satisfied by joining the drama club. The substituted goal often becomes disproportionately emphasized when compensation is used. The individual's new motive sometimes seems unusually strong. Another way of reacting to this frustration might have been the *withdrawal* into fantasy. Instead of changing one's goals, the individual withdraws to a situation where the frustrations are not so great. Which behavior pattern is chosen depends in large measure on which patterns have been most rewarding in earlier experiences.

A common reaction to frustration is *aggression*. This involves striking out against the apparent obstacles to the satisfaction of a particular motive. Aggression seems always to be the result of frustration, although, as we have seen, other results are possible. We see aggression most directly in children, when the frustrating object is attacked directly. The parent may be kicked in the shins or the little brother hit over the head with the toy fire engine. Often aggression of this type has adaptive characteristics in satisfying the need, and if it does the individual may learn such a habit (for example, kicking a door that is stuck may actually open it). However, in adults we find aggression most frequently directed against substitute objects which are more easily accessible, more acceptable socially, or less dangerous. Thus, the man who is "bawled out" by his foreman may go home and abuse his wife. She, in turn, may strike the child for a minor offense. It has been shown, in this connection, that unhappily married parents are much more likely to be strict and abusive in raising their children. Such children, in turn, may take their aggression out on their school, smaller children and pets, and society. A well-known example of displaced aggression is the *scapegoat.* Scapegoating appears to be more prevalent during periods of social unrest and frustration.

Rationalization is one of the more harmless ways that individuals learn to deal with frustration. The "sour grapes" expression applies to this kind of response. The student who fails blames it on poor teaching; the worker who does not get promoted states he did not want the new responsibility.

Frustrations may be dealt with in other ways. Some of these methods are so extreme that they interfere with everyday living. While there is no sharp line, serious failures of adjustment to conflict and frustration characterize the serious mental disorders, of which the two major classes are *psychoneuroses* and *psychoses.* An example of the former type of disorder is one in which the individual "regresses" to childish levels of behavior, in which he feels greater security and does not have to face the conflicts of adult life. In the latter kind of disorder, as an example, the individual may "withdraw" from reality to such an extent that he continually stares into space, out of touch with his environment.

MOTIVATION AND PERFORMANCE

We have seen that motivation may have many forms, ranging from basic physiological needs to intricate and subtle patterns of social motivation like the needs for affiliation and status. We have also noted that, whatever its particular origin, a motive functions to energize behavior and to channel it toward a goal. What happens to behavior when variations occur in the *amount* of motivation? What are the observable effects of increases in this energizing and directing property of motivation?

It is a well-known fact that human performance of almost any sort is improved by increases in motivation. All of us are urged to "do our best" whenever some kind of performance of importance to us is being assessed. School children are cautioned to "try hard" on examinations, because it is generally known that a highly motivated performance will be better than one exhibited by a child who "doesn't care." The pep talk that the coach gives to his team is designed to call upon reserves of motivation which may produce in each player that crucial extra bit of heightened performance needed to win the game. National safety campaigns are devoted largely to the attempt to instill greater motivation in all of us to perform in accordance with accident prevention rules.

Human activities, as we have pointed out in previous chapters, depend largely upon retained habits and skills which have been acquired through the process of learning. Furthermore, as the number of occasions or the time devoted to learning increases, the *level of skill* which is stored in memory also increases, up to some ceiling imposed by the capacities of the nervous system. Below this ceiling, the performance which is displayed on any occasion is usually heightened by increased motivation, lowered by decreased motivation. (Some limits should be placed on this statement, since extremely high motivation sometimes interferes with performance.) Even when levels of skill are high, because learning has taken place on many occasions, the performance of human activities is affected by changes in the amount of motivation. A highly skillful automobile driver, whose motivation has been lowered perhaps by conflict or frustration, may actually drive less well and be more prone to accidents under such circumstances.

Performance = Skill × Motivation

How does motivation interact with level of skill to affect performance? Can we think of motivation as simply adding something to the skill, or to the responses made when the skill is utilized? Actually, there is much evidence to make us think that motivation does not simply *add* to skill in producing performance, but rather *multiplies* with it. This conception of the effect of motivation is quite consistent with our everyday experience, which tells us that complete lack of motivation (a *zero* motivation) means no performance at all. In addition we know that a person of mediocre skill can sometimes beat an "expert," if he is inspired with high motivation. In other words, motivation can make a tremendous difference in performance, not because it adds to skill, but because it multiplies with it. We can express this effect as a formula:

$$\text{Performance} = \text{skill level} \times \text{motivation.}$$

Effects on Task Performance

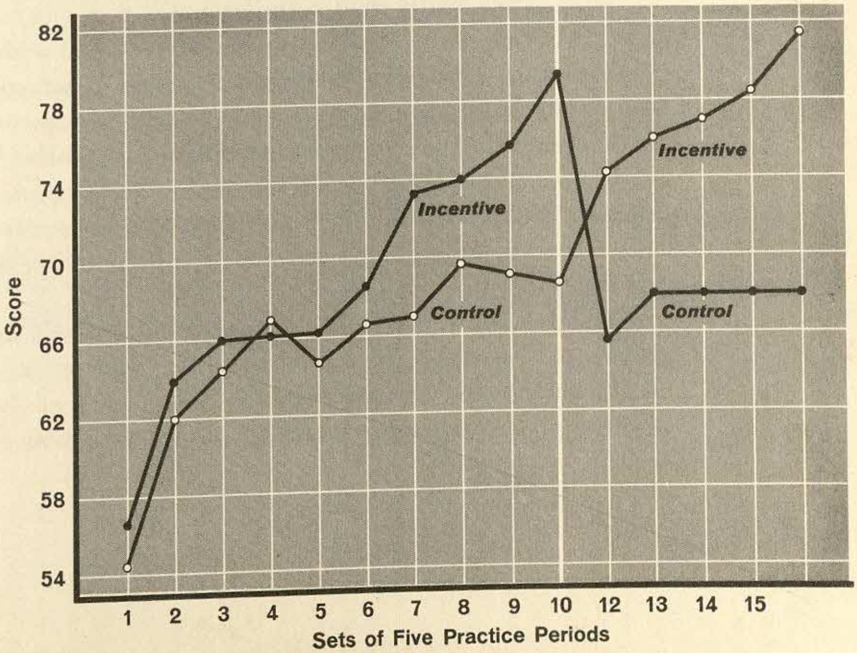
This multiplying effect of motivation may be observed in the performance of tasks representing all types of human functioning. For example, when we ask a human being to discriminate a tone from a just slightly louder tone, considerable care must be taken to motivate him to report the slightest possible difference he can distinguish, if we are to obtain a true measure of discrimination. Anyone can discriminate large differences "without half trying"; but really small differences will not be responded to without high motivation.

Responses which depend upon simple habits are likewise greatly affected by motivation, as studies with animals and children demonstrate. Hungry rats exhibit greatly improved performance in approaching a white door for food, for example, than do less hungry or well-fed rats. Verbal sequences and motor skills are likewise influenced by the multiplying effects of motivation, as are concept-using functions. Many studies have demonstrated improvements in performance of simple games and school tasks resulting from increases in motivation. As we have previously mentioned, the addition of incentives has frequently been shown to improve performance in verbal-sequence tasks like spelling and reading, as well as in conceptual tasks like solving arithmetic problems.

The effects of special incentives, as well as their removal, on the performance of the motor task of printing the letter "a" by a group of college students is illustrated in Figure 4.16. In this study, one group (the control) practiced the printing task with instructions to work as rapidly and conscientiously as they could. An experimental group was provided with several incentives designed to increase their motivation, including knowledge of their scores after each trial, frequent encouragement and various forms of verbal urging to do their best. After 50 trials, the conditions were reversed for the groups for the remaining 25 trials. The effects of adding incentives on this performance were quite marked, as shown in the figure. Equally striking is the fact that performance dropped off almost immediately when the added motivation was removed.

Identifications based on retained models are also affected by motivation, in the expected manner of improved performance. It is probable, too, that the models themselves may be "distorted" by motivation in other ways. For example, it is common for people to see (that is, identify) what they most need to see. The lover is "blind" to defects in his loved one which

FIGURE 4.16. *Effects of special incentive conditions on the performance of college students in making the letter "a." (Data from Book, W. F., and Norvell, L., The will to learn: An experimental study of incentives in learning, Ped. Sem., 1922, 29, 305-362)*



may be obvious to other people. Later on (in Chapter 7) we shall describe a study which showed that poor children identified dimes and other small coins as larger than did children from more wealthy families. Presumably, their need for money is stronger, and this motivation is reflected in their identifications of the coins as bigger.

The powerful effects of added motivation are used extensively in industrial situations, and Figure 4.13 provided an example. Particularly to be noted is the fact that the workers in this experiment were quite highly skilled. Their performance over a period of weeks preceding a change in pay incentives appears to have reached a stable level, reflecting a similarly stable skill. Yet, for most tasks, changing motivation had a remarkable effect on production.

SUMMARY

Behavior is energized by *motivation.* In its basic form, motivation is a fundamental characteristic of life, arising from the interaction of an organism with its environment. The internal organs of the body tend to maintain a constant internal environment, essential to survival, by the process of *homeostasis.*

Against this background of internal self-regulation, the organism is frequently required to restore states of equilibrium by interaction with the environment. Behavior that is instigated by a state of disequilibrium or deficit within the individual is said to be *motivated.* The state of disequilibrium is called a *need,* and the term *drive* is used to refer to the impetus this need gives a behavior. A drive implies also *direction* toward some particular *goal.*

In a normal environment, a need typically produces *heightened activity,* and such activity is often used to measure the *strength of drive.*

The cycle of motivated behavior can be observed in physiological needs which originate primary drives. Some of the best-understood drives are hunger, thirst, and sex. Recent studies have been made of a newly identified drive called "contact comfort." Physiological needs exert their influence on behavior through neural centers, some of which have been shown to exist in the *hypothalamus,* a part of the brain just below the cortex.

While primary drives are inherited, many needs are *acquired* by a process of learning. The learning of such motives as acquiring money (poker chips to be exchanged for food) and fears has been demonstrated in animals. Human beings *acquire* many different motives in the course of their lives. These operate to energize and direct behavior just as effectively as do the basic physiological needs.

Some of the most important acquired motives in human beings are *social motives,* which differ among different cultures. In our society, some of the needs which have been recognized as significant are *affiliative* needs, *status* needs, and *acquisition* needs.

Considerable study has been devoted to the effectiveness of different kinds of *incentives* in motivating behavior. Frequently used incentives in the control of behavior of both children and adults are praise and reproof, punishment, money, participation, competition and cooperation.

Motives frequently operate in combination with each other, and sometimes in competition. Many situations give rise to a *conflict* of motives, which may lead to a *frustration* of one motive while others are being satisfied. Frustration gives rise to various recognizable behavior patterns by means of which the individual attempts to deal with the conflict situation. Among the best-known of these are *aggression, compensation, rationalization,* and *withdrawal.* Serious conflicts of a continuing nature may lead to symptoms of mental disorder.

Motivation *multiplies* with level of skill to determine the performance of human beings. Even when skill levels are high, increased motivation frequently raises the level of performance to a considerable degree. The performance of tasks in all categories of behavior has been shown to be influenced by motivational changes.

READING REFERENCES

Haire, M., *Psychology in management.* New York: McGraw-Hill, 1956. A discussion of needs and motives with implications for supervision in industry.

Miller, N. E., Learnable drives and rewards, Ch. 13 in Stevens, S. S. (Ed.), *Handbook of experimental psychology.* New York: Wiley, 1955. The experimental basis of acquired motivation.

Stagner, R., and Karwoski, T. F., *Psychology.* New York: McGraw-Hill, 1952. Discusses in detail the concept of homeostasis in relation to motivation.

Viteles, M., *Motivation and morale in industry.* New York: Norton, 1955. Reviews research on motivation and morale in industrial settings.

5

HUMAN ABILITIES

Previous chapters have described the subsystems of the behavior system. We now turn our attention again to the varieties of human activities identified in Chapter 3. One of the most obvious facts about human performances, of whatever type, is that they differ from each other in degree or level of excellence. The nature and importance of these individual differences is what the present chapter is all about.

When we search for the causes for individual differences, we find that human beings come to any given task with differing sensory capacities and different backgrounds of stored experiences. These are called general abilities. These abilities in which people differ mean that one individual will learn a new task with a different facility than will another individual. Each ability supports a great variety of specific human performances. These performances are related to each other insofar as they draw upon the common ability. The learning of particular skills, which we shall discuss in the next chapter, begins for the individual at a level determined by his abilities. You will learn in this chapter how human abilities are identified and measured, and what some of the most important ones are.

We have seen that the behavioral system, energized and directed by motivation, can display various functions common to all human beings, including discrimination, identification, verbal and motor sequences, concept-using and thinking. In this chapter, we shall begin to consider how the specific activities in these categories *develop within the individual.* For these common behavioral functions, we know, develop within a framework of anatomical structures which is unique for each individual. Behavior is also shaped by learning that occurs in differing social and cultural environments. Because of his inheritance, each individual begins life with a particular set of sensory, effector, and neural structures which set limits to his development. Because he is subjected to a particular set of environmental influences from birth onward, what he learns is also an individual matter.

The end result is a great variety of possible ways in which human individuals can differ from one another. One of the major tasks of psychology has been to discover and describe the ways men differ, to measure the extent of these differences, and to evaluate their importance in various human performances. We need to understand not only how people are alike, but also in what ways each individual's behavior is unique.

Everyone knows that people differ from each other in physical appearance, weight, and height. It is also recognized that people differ in their performances. However, the nature and extent of these performance differences, as well as their practical significance, are matters that require fuller consideration. For example, despite the common belief that "practice makes perfect," no amount of practice will make one man as proficient at some particular task as a little practice will make some other man. How can we account for this? One reason is that individuals begin the learning of new habits, identifications, motor skills, and concepts with differing *capacities* and *backgrounds of stored experiences.* In other terms, people differ in the *abilities* they bring with them to particular tasks.

In this chapter, we shall describe the basic abilities which make people different from one another. We shall discuss how these abilities are identified and measured, and how they are related to the process of learning and to the various kinds of performances of which human beings are capable.

THE CONCEPT OF ABILITY

If several individuals learn a complex task, such as "flying" a Link trainer or solving calculus problems, we will find that the entire group improves its performance as training continues. The degree of improvement will depend to a large extent on the particular conditions of learning employed (about which we shall have more to say in Chapter 6). But even if all the individuals are trained under exactly the same learning conditions, we will find marked differences between them in (a) the rate at which they improve initially and (b) the final level of proficiency they attain, beyond which they do not improve very much. Examples may be found in the learning curves shown in Figures 5.1 and 5.2. Differences in proficiency between individuals persist even if they are all subjected to identical training. Rarely is it found that training reduces the differences between people. Perhaps even more important is the common finding that training may actually increase these individual differences. Figure 5.2 presents an example of results of this sort obtained in the practice of a numerical task. It is clear that the subjects differed more at the completion of practice than at earlier stages of practice and that, during these stages of learning, this difference

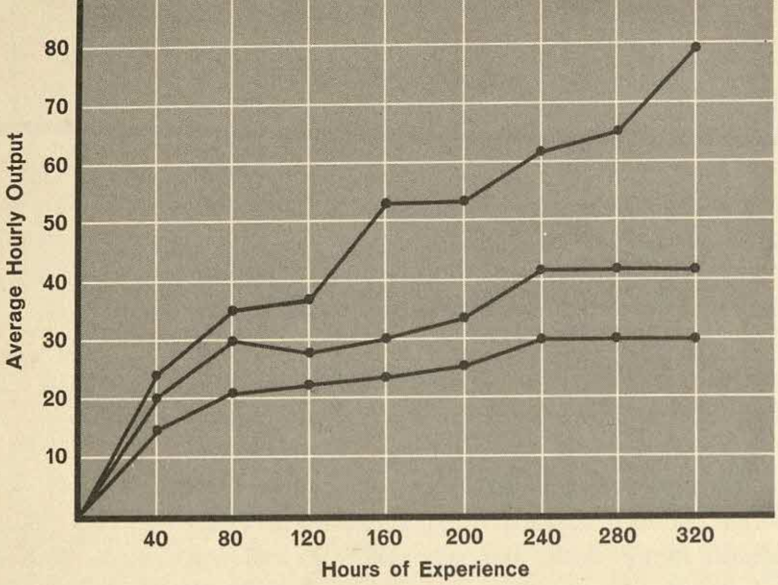


FIGURE 5.1. *Learning curves for three textile workers. These workers differ in their rate of progress (seen in the steepness of the curves), the length of time over which improvement continues, and their final proficiency level. One worker is still improving markedly. The curves also show that differences between these workers increase with practice. (Data from* McGehee, W., *Cutting training waste,* Pers. Psychol., *1948, 1, 331-340)*

FIGURE 5.2. *Learning curves for three individuals practicing addition. Subjects practiced for five-minute periods on each of 30 successive days. (Data from* Vitelis, *M. S.,* Industrial psychology. *New York:* Norton, *1932, p. 105)*

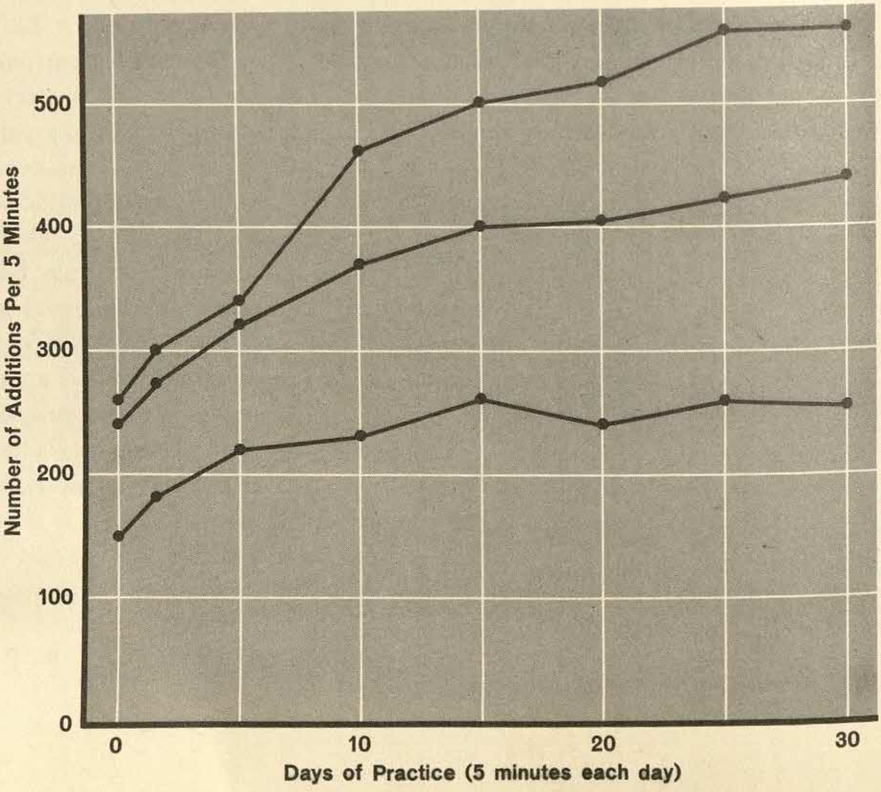
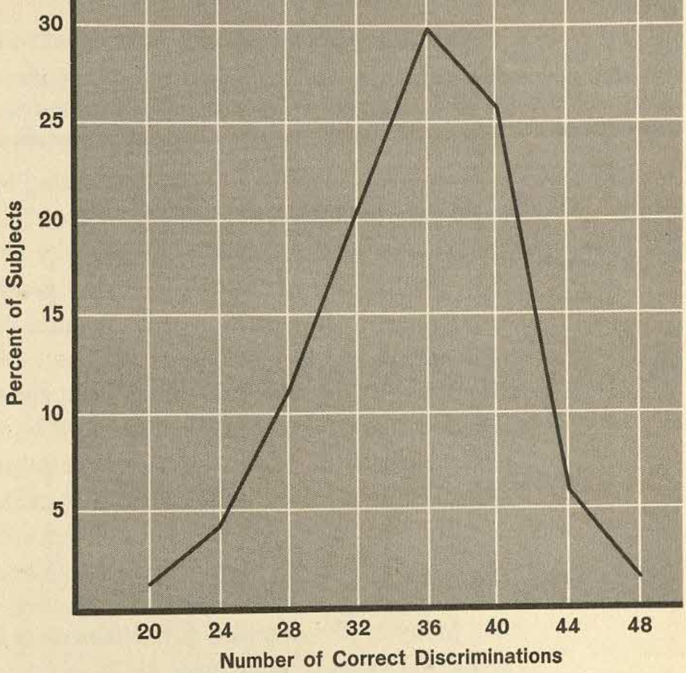


FIGURE 5.3. *Distribution of scores made by different individuals on an auditory test of intensity discrimination. Individuals were required to state which of two sounds was louder. (After Fleishman, E. A., and Spratte, J. G.,* The prediction of radio operator success by means of aural tests. *Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1954, Technical Report AFPTRC-TR-54-66)*



increased progressively. Figure 5.1 shows similar results for an industrial job in the textile industry. It can be seen that the operators were much more like each other in terms of performance earlier in training than in the intermediate stages, or even after they had had two months of experience on the job.

In Chapter 7 we shall examine some of man's capacities for making discriminations between physical stimuli. For example, evidence on man's capacity to discriminate between intensities of sound (or loudness) indicates that he is better at discriminating sound intensities when these are presented in the middle range of audible frequencies (1,000 to 5,000 cycles per second). While this is extremely important information, it should be noted these results are based on *averages* of adults with "normal" hearing. It is equally important to know the extent to which people may *differ* from one another in their ability to discriminate sound intensities when all individuals are subjected to the same range of auditory stimuli. Figure 5.3, for example, represents scores on a measure of discrimination of sound intensities applied to 250 Air Force basic trainees having "normal" hearing. It can be seen that there is considerable variation in the scores achieved by these "normal" subjects in this auditory function. Similar distributions of scores were obtained for these same individuals for discriminating other kinds of differences in sound stimulation; namely, frequency (pitch), and duration.

An important question is how these individual differences in auditory discrimination are related to the differences among these same individuals on other auditory tasks. For example, do people who attain high scores on these measures of auditory discrimination perform better than other people in such complex auditory tasks as learning Morse code signals, interpreting sonar returns, identifying sounds in the Chinese language, and composing music? Is the discrimination of intensity or of pitch (or both) related to these performances? Furthermore, do people who perform well on pitch discrimination also perform well on intensity discrimination? Such questions get us closer to the sorts of things the psychologist wants to know about man's basic abilities and how they are organized. If, for example, it is found that excellent discrimination of both pitch and intensity facilitates performance in a variety of more complex auditory tasks, then we may speak of these as *basic abilities.*

Basic Abilities and Skills

Many of the complex performances and activities of man can be described in terms of more basic ability components. These basic abilities are relatively enduring characteristics of individuals, in which people differ appreciably from one another, and which affect the performance of a great variety of specific human tasks. The term *basic ability refers to a general trait of an individual which determines the limit of performance he attains on many different tasks.* For example, the level of performance a man attains on a turret lathe may depend on the level of his basic abilities of manual dexterity and motor coordination. However, these same basic abilities may be important to proficiency in other tasks as well. Thus, manual dexterity is needed in assembling electrical components, and motor coordination is needed to fly an airplane.

The term *skill* is a more specific term, which refers to proficiency in a specific task or a limited group of tasks. Thus, when we speak of a person acquiring the skill of operating a turret lathe, we mean only that this person has acquired the sequences of responses required in this specific task.

Basic abilities represent stored *general* potentialities which can facilitate the learning of a variety of *specific skills.* Thus, people with a high level of *manual dexterity* may more readily learn the specific skill of lathe operation. Of course, some abilities may transfer to a greater variety of specific tasks than others. For example, in our culture, *verbal* abilities are more important in a greater variety of tasks than some other types of basic ability. The individual who has a great many highly developed basic abilities can become proficient at a great variety of specific tasks. The concept of "intelligence," which we will discuss later, really refers to a combination of certain basic abilities which contribute to achievement in a wide range of specific activities. It is important to keep in mind the distinction between basic abilities and the later acquisition of specific skills. As we shall see, this allows us greater precision in describing, understanding, and predicting many complex human performances.

THE DEVELOPMENT OF BASIC ABILITIES

Physiological Bases

Biological and physiological factors play an important role in determining one's basic abilities. For example, the absence of well-developed cones in the retina of the eye will certainly limit the kinds of visual discriminations an individual is able to make. In the case of motor abilities, individual differences may depend on the sensitivity of sense organs in muscles and joints, on the composition of muscular tissue, or on differences in the structure of the central nervous system. Most abilities undoubtedly depend in part upon combinations of physiological factors associated with the human nervous system, as well as the receptors and effectors. The particular genes transmitted through heredity play a significant part in determining one's basic abilities. However, these genetic factors are thought mainly to fix limiting conditions, within which a wide range of variation is still possible.

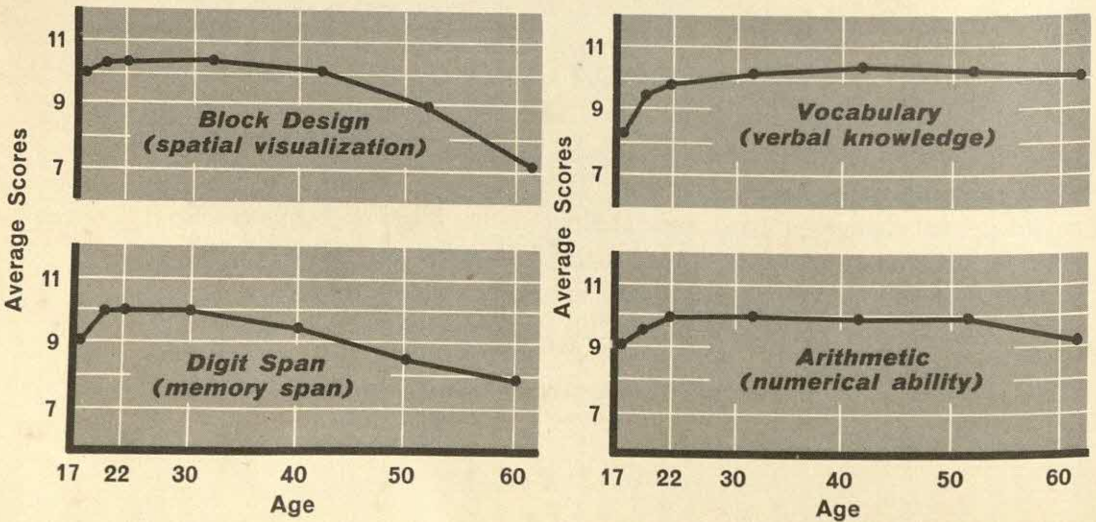
The Role of Learning

Within the boundaries set by heredity, environmental factors and learning play a major role in influencing ability development. In fact, most of the abilities of man can be considered as attributes of behavior which, in the human adult, have attained considerable stability through the learning that has taken place during his entire life. The whole process of formal education is, of course, based on this principle. While many specific skills like reading and writing are deliberately taught, at the same time certain more general abilities are being developed—for example, verbal ability and reasoning ability. Generally, it is believed that the longer and more intensively an individual is exposed to a school environment, the more will the abilities developed there contribute to his later achievements.

Our definition of basic abilities includes the notion that these are relatively enduring traits of the individual. Unless he is subjected to marked environmental changes, a man's basic abilities are not likely to change much once he reaches adulthood. Thus, such abilities as numerical ability, manual dexterity, and reasoning ability are fairly stable attributes of behavior over lengthy periods of time. This probably results from the fact that they have been learned, relearned, and practiced so many times during the individual's lifetime. In Chapter 6, we will discuss the process of "overlearning." This refers to a learning situation in which practice continues well beyond the point where the final level of performance is reached. When this happens, individuals may show no impairment of performance even after lengthy periods of time without practice. Probably man's abilities are stable because certain kinds of human performances have been practiced in varying degrees throughout an individual's lifetime and have become "overlearned." Figure 5.4 illustrates the relative stability of a number of human abilities. It can be seen that, typically, no improvement and very little fluctuation in the levels of abilities occurs during much of the adult life span. Some decline with age often occurs, but this is true only of some abilities, not all.

Human adults, of course, show marked learning over time in practically any type of specific skill. In fact, improvements in performance on particular tasks may continue over several years. For example, Figure 5.5 shows learning curves for groups of sewing machine operators who practiced the task every day. Even after two years there was still some steady improvement. At such high levels of proficiency, even slight improvements can be of considerable practical importance. Despite such instances of long-continued improvement, the rate of learning and the final level achieved by particular individuals are both limited by the basic abilities of these individuals. The fact that these basic abilities are themselves fairly stable allows us to make useful predictions about subsequent performance in specific tasks. For example, knowledge about a person's numerical ability helps us predict his probable success later on in engineering training.[1]

FIGURE 5.4. *Ability level in relation to age. Data are from certain subtests of the Wechsler Adult Intelligence Scale. The ability measured is given in parenthesis under the subtest name. (After Doppelt, J. E., and Wallace, W. L., Standardization of the Wechsler Adult Intelligence Scale for older persons,* J. abn. and soc. Psychol., *1955, 51, 312-330)*



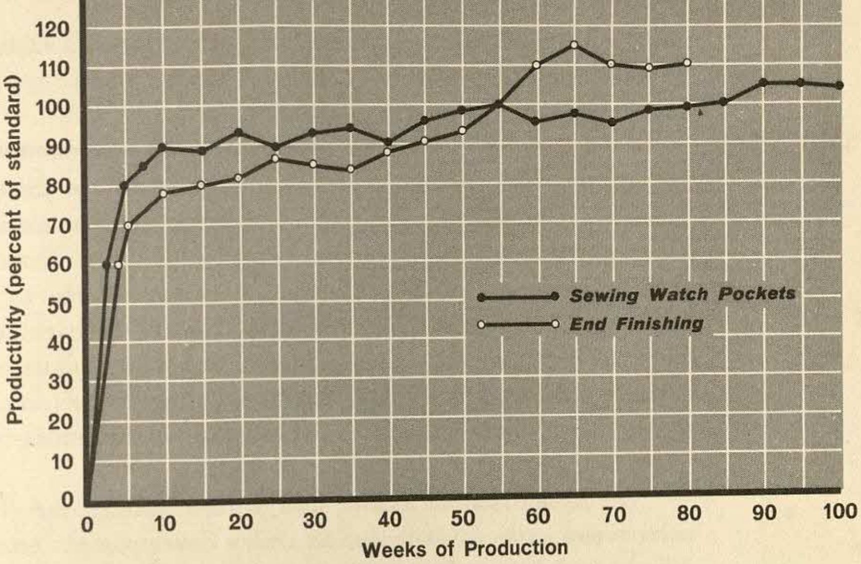


FIGURE 5.5. *Learning curves for two different jobs requiring the operation of a power sewing machine. These workers were paid on a piece-rate system. (After Taylor, J. G., and Smith, P. C., An investigation of the shape of learning curves for industrial motor tasks,* J. appl. Psychol., *1956, 40, 142-149)*

Environment, Culture, and Ability

Basic abilities begin to be acquired early in life. Accordingly, early childhood environment, particularly the cultural setting in which children grow up, has considerable importance for the development of basic abilities. Cultural forces often prescribe what shall be learned and at what age. Children reared in different cultures, which demand different types of learning during childhood, tend accordingly to develop different patterns of basic abilities. This observation has been made in studies comparing the abilities of children among such widely differing groups as mountain people, Eskimos, Australian aborigines, English canal-boat people, gypsies, Hopi Indians, and American city-dwellers.

Dramatic examples of the influence of early environment on abilities are also found in studies of chimpanzees raised in a "human" cultural environment. In a recent series of studies, Viki, a female chimp, was adopted a few days after birth and raised in the experimenter's home until her death from a virus infection at age six and a half.[2] Viki was clearly better at problem-solving than apes previously studied in the laboratory, and proved to be as good at it as human children of her age. She developed good manual dexterity and proved skillful in the use of tools and mechanical gadgets. On nonverbal tests of intelligence, she performed as well as children her age. Her language development lagged behind, but she could say something approximating "mamma," "papa," and "cup" in the appropriate situations.

Evidence of the detrimental effects of environmental influences on abilities comes from studies of "wild children" who are discovered to have been living in isolation or in exclusive contact with animals.[3] These "wild children" include some who have apparently been abandoned or have wandered off and survived through their own efforts, as well as others reared by such animals as the wolf and bear. Such children have been found to show inability to say anything resembling human speech, difficulties in depth and space perception, unusual agility in locomotion (usually on all fours), and modifications of sensory identifications in the senses of smell, hearing, and sight.

We do not have to look to such extreme cases to note the influence of culture and early environment on ability development. Analyses of ability differences between socioeconomic groups and between cultural regions reveal marked differences in the ability patterns which develop. Each subculture fosters the development of its own pattern of abilities. For example, it has been found that higher socioeconomic groups tend to excel in numerical ability, verbal comprehension, and word fluency, whereas differences in spatial orientation, reasoning, and verbal memory abilities among socioeconomic groups are not as marked. Manual dexterity has been found to be higher in lower economic groups.[4]

Comparisons of abilities in different immigrant groups in this country are also of interest here.[5] First-generation Jewish children and adolescents often excel on abstract thinking and verbal tests, but do not score as high on problems dealing with spatial relations or manual dexterity. Scandinavian children excel on tests requiring spatial orientation and sensory-motor coordination. American-born children of Italian parentage do relatively well on tests of manipulative abilities, but less well on tests of verbal abilities. These differences between subcultures tend to disappear with succeeding generations.

The Rate of Ability Development

Before reaching a fairly stable level in adulthood, different basic abilities develop during childhood and adolescence at different rates. This of course is partly due to some of the environmental factors discussed above. The other major reason is bodily growth. There is a definite sequence of developmental stages in the structural characteristics of the individual. As the child grows older his bodily proportions change, muscles become stronger, and certain modifications occur in the nervous system. This

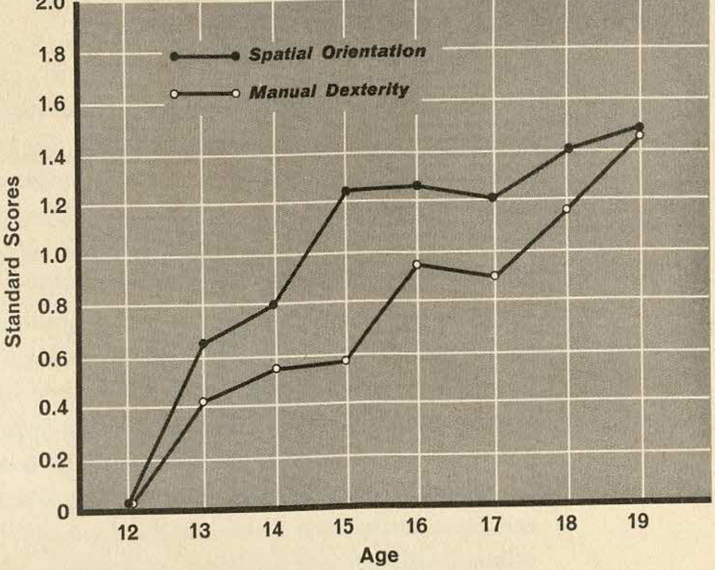


FIGURE 5.6. *Development of two abilities. Curves show test scores of adolescent boys at different ages. (After Jones, H. E., and Seashore, R. H., The development of fine motor and mechanical abilities, 43rd Yearbook, National Society for the Study of Education, 1944, Part I, 123-145)*

growth process, which occurs independently of learning, is known as *maturation.*

As structures change with age, the basic abilities which depend on these structures also change. For example, no amount of practice will enable a child to walk or climb until particular muscles become sufficiently strong. The particular structures involved in other types of abilities are not so well known. Furthermore, the influence on abilities of maturation and learning are so intertwined that it is difficult to separate the unique contribution of each at any age level. Nevertheless, it is still possible to trace the development of abilities in the individual at successive ages. In general, even within a particular culture, different basic abilities develop at different rates. Moreover, as particular abilities develop, they may remain fairly stable over limited periods at particular age levels before further development occurs. An illustration of this for two basic abilities is provided in Figure 5.6. The curve depicting development of spatial-orientation ability shows a definite negative acceleration, rising until about age 15 and then leveling off. The curve for manual dexterity, on the other hand, is more nearly linear. Both curves show a step-like increase indicating little improvement at certain age levels, but these "steps" occur at different age levels and for different intervals in the two curves. Similar curves could be obtained for other basic abilities. We have already seen in Figure 5.4 that such curves tend to level out and show little improvement beyond age 22.

The Differentiation of Basic Abilities

Another important phenomenon connected with ability development is that of *ability differentiation.* To illustrate, let us consider ability in the very young. There are only a limited number of ways we can describe the abilities of an infant. In fact an infant's general ability (or "intelligence") is typically evaluated in terms of his performance on manipulative or motor tasks. Consequently, the basis on which the infant's subsequent basic abilities are predicted is in fact his motor ability. And the predictions about future abilities made on this basis are not very reliable. But as the child develops, it becomes possible to differentiate between his verbal and motor development. Shortly, we can even be more precise than this. We can talk about particular basic motor abilities (e.g., coordination, dexterity) or particular verbal abilities (e.g., fluency, comprehension) and we may even find the same individuals to be advanced on one basic ability and lagging on others. Although the prediction of a child's relative standing on one motor ability from his standing on another is fairly good during infancy, as he grows older we become aware of the development of new basic abilities (e.g. visualization, pitch discrimination) and increasing specialization. That is, the older child tends increasingly to be much better at some things than at others. Through this process of differentiation, abilities become more clearly defined and more distinct from each other. Thus, in the adult we cannot make very good predictions about a person's spatial ability just because we know his verbal ability or numerical ability. This process of increasing distinctiveness of basic abilities is what we mean by *ability differentiation.* As a consequence of it, we are able to make increasingly precise predictions of how individuals will differ in their performance of a variety of specific tasks.

IDENTIFYING BASIC ABILITIES

In the preceding sections, we oversimplified our description of how man's basic abilities are discovered and identified. How does the psychologist identify an ability and distinguish it from numerous other abilities? How is it determined that an ability is really general in the sense that it contributes to the learning of a number of different tasks? We need to examine these procedures more closely.

First of all we need to reemphasize the point that abilities are measured in terms of human performance. No one has ever seen an "ability" any more than anyone has seen an "electric current." We infer that ability exists from its effects, from measurements of observable human performance.

The main approach to the discovery of general abilities makes use of the mathematical concept of *correlation,* which may be understood in terms of the following example. Performance measures for a large number of individuals are obtained on a variety of different tasks. As we know, these people will differ in the scores they achieve on each task. Now, the question to be asked is, "To what extent is a subject's relative standing on one task related to his standing on the other tasks?" In mathematical terms, "What is the correlation among performances?" If, for example, all individuals rank themselves in the same order in performing all the tasks, we can obviously predict a particular person's standing on any task from knowledge of his performance on any other task. We would say the correlation between performances on such tasks is perfect. If this were the case, it could be concluded that a single basic ability is involved which is general to all the tasks investigated. If, at the other extreme, it were impossible to predict performance from any one task to any other, the degree of correlation would be zero. In such a case we would conclude that each task depended on a different ability, and that there are as many abilities represented as tasks. In most investigations of this type, however, we rarely find either extreme. Usually, it is found that performance on certain tasks is predictive of performance on certain other tasks, but not predictive of others. Moreover, it is usually found that there are groupings of tasks on which the same people tend to do well (or poorly). From the kinds of performances required by these task groupings, the psychologist names the more general abilities involved.

As a specific illustration, we use the measurement of motor abilities. Tasks such as chinning, pushups, broad jumps, etc., seem to have something in common. Frequently such tasks are referred to as indicators of general physical proficiency. But what are the correlations among such performances? Is there a single common ability which accounts for proficiency in all these tasks and which we can call general athletic ability? Other questions can be asked. For example, fine manipulative performances (such as those involved in assembling small parts, in threading needles, in manipulating tools) also are motor tasks. Is there a general motor ability which facilitates performance in both fine manipulative tasks and gross physical-proficiency tasks? If so, the same people should do well in both types of tasks.

In an investigation of these problems, the performances of a group of 400 young men were measured on 40 different tasks, including 23 physical proficiency and 17 manipulative tasks.[6] Measures of correlation were obtained among all the tasks. The results showed that the abilities contributing to performance on gross physical tasks are independent of those contributing to fine manipulative skill. That is, there appeared to be no "general motor ability." In addition, the correlations showed that there is not even any general "athletic ability," or "manipulative ability." Instead, each of these areas in turn breaks up into smaller clusters of correlated performances which represent the basic abilities. Among the fine manipulative tasks, there were four main groupings of tasks. The same people tended to do well on tasks involving arm-hand manipulations. This common ability was called *manual dexterity*. Others seemed to do well on tasks emphasizing manipulations with the fingers (*finger dexterity*). The two remaining ability categories were named *arm-hand steadiness* and *aiming*. In the physical proficiency area, the tasks grouped into ability areas of *strength, flexibility, balance, gross body coordination,* and *energy mobilization.* We shall have more to say about these abilities later. For the present we note only that this study illustrates the way in which abilities are identified by correlation of performance measures. The object of such an investigation is to discover the abilities which underlie performances in a wide variety of different tasks. As we shall see in a later section, similar analyses have been made on other ability domains such as identification and concept-using.

The ability categories discovered in this way are important to our understanding of human behavior. They also have many practical consequences. Ability categories may be used to describe the requirements of industrial and military jobs. They also provide a basis for developing psychological tests used for personnel selection and vocational guidance, as we will see in Chapter 11.

Correlation

Since the mathematical concept of correlation is central to our discussion of abilities and to many other areas of scientific psychology, we should examine it more closely. To do this we return to the study of motor abilities just described.

Suppose we want to know if there is a relationship between the number of pushups a man can do, and the number of times he can chin himself on a chinning bar. Consider Table 5.1, which contains data obtained from 10 subjects. By inspection of the table we note some relationship between the scores made by these 10 individuals on chinning and pushups. In general, those scoring high on pushups score high on chinning. However, it is also evident that the relationship is not perfect. How high is the relationship? To get a better idea we can plot these data on a *scatterplot*, as illustrated in Figure 5.7. This gives a graphic representation of these data. As can be seen, if we know a man scored high on one task the probability is high that he also scored high on the other. But we cannot predict one score from

TABLE 5.1
SCORES MADE BY TEN INDIVIDUALS ON TWO MEASURES OF PHYSICAL FITNESS

Subject	*Number of pushups*	*Number of "chins"*
A	5	6
B	25	8
C	20	2
D	15	4
E	10	14
F	30	12
G	35	18
H	40	21
I	45	10
J	50	16

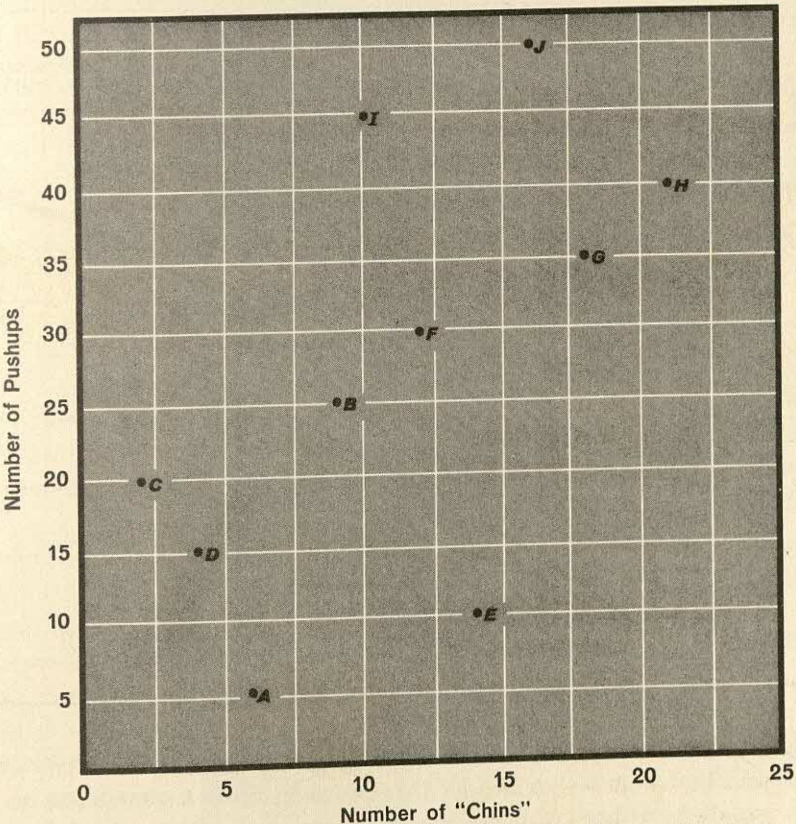


FIGURE 5.7. A "scatterplot" showing the relationship between scores on pushups and chinning made by ten individuals. For each individual, a single point is plotted which shows his standing on both measures.

another with perfect accuracy. To express the extent to which prediction can be made, we need a *measure* of the *degree* of this relationship. This is expressed by the *correlation coefficient*, which can vary on a scale from +1.00 to −1.00. One of the simplest methods of computing this measure begins by assigning a rank to each person on each task. (There are more precise formulas which make use of actual scores rather than ranks, but this will serve our purpose.) Table 5.2 has done this for the data in Table 5.1. The correlation coefficient is then computed by the following formula:

$$\text{Rho (Coefficient of Correlation)} = 1 - \frac{6(\text{sum of } d^2)}{n(n^2 - 1)}$$

in which d is the man's difference in rank on the two tasks, and n is the number of subjects in the sample. For the present data, the correlation coefficient is found to be +.61. This indicates a fairly high relationship between scores on chinning and pushups.

TABLE 5.2

RANK ORDERS OF THE TWO SETS OF PERFORMANCES IN TABLE 5.1 AND THE COMPUTATION OF THE CORRELATION BETWEEN THEM

Subject	*Rank on pushups*	*Rank on "chins"*	*Difference in ranks (d)*	d^2
A	10	8	2	4
B	6	7	1	1
C	7	10	3	9
D	8	9	1	1
E	9	4	5	25
F	5	5	0	0
G	4	2	2	4
H	3	1	2	4
I	2	6	4	16
J	1	3	2	4

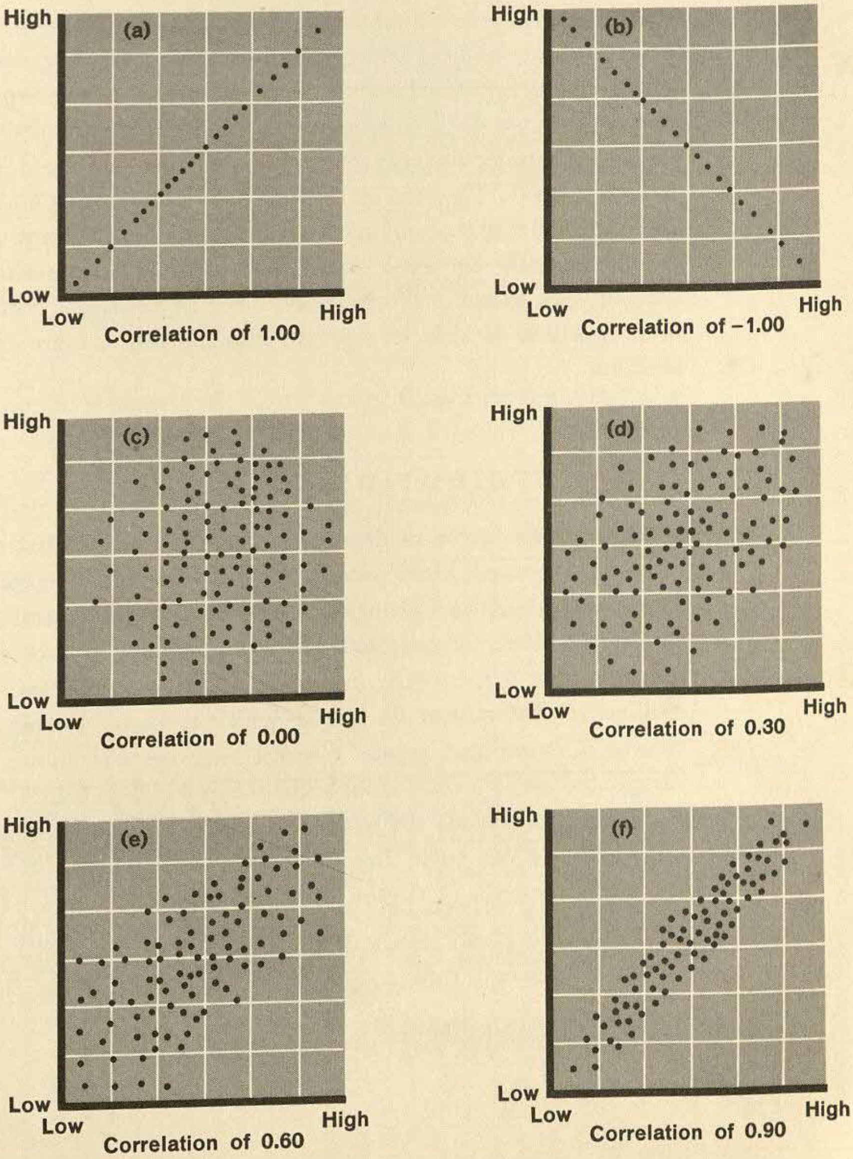
Sum of $d^2 = 68$

n, or number of subjects = 10

$$\text{Rho} = 1 - \frac{6(\text{sum of } d^2)}{n(n^2 - 1)} = 1 - \frac{6(68)}{10(100 - 1)} = .61$$

A correlation of +1.00 would have been obtained if the subjects had shown identical ranks on each of the two tasks. With a correlation of +1.00 we would have been able to predict perfectly a person's standing on one task from his performance on the other. A perfect correlation is practically never obtained in measures of human behavior. Such relationships are not uncommon in the physical sciences, however. For example, Figure 5.8a could represent the relationship between temperature (on one axis) and the length of a column of mercury (on the other axis). Figure 5.8 illustrates the scatterplots for six different patterns of correlations. It can be seen that negative correlations are possible. A negative correlation indicates an inverse relationship between two measures. This is the case, for example, when amount of muscular tremor is correlated with accuracy scores in rifle marksmanship. In general, the less the tremor the higher the score. A perfect negative correlation (−1.00) such as that illustrated in Figure 5.8b would be represented by a scatterplot between measures of the volume of a gas and its pressure with temperature held constant. Figure 5.8 also

FIGURE 5.8. *Scatterplots illustrating five different correlation patterns.*



shows the scatterplot for a zero correlation, which indicates that two measures are unrelated. A scatterplot between a measure of vocabulary size and a measure of manual dexterity would look like this. Thus, the correlation coefficient may vary from +1.00 to −1.00, and the nearer it is to either of these extremes the higher is the degree of relationship.

To return to our example, we noted a correlation of .61 between chinning and pushup performance. This shows that the same ability is required by both tasks. For these same subjects, scores on chinning were also plotted against scores for sit-ups. In this case the correlation was found to be close to zero. Apparently, performance on chinning is not predictive of sit-up performance. Now let us examine one final set of relationships, the performance of our subjects on sit-ups and pushups. Here a substantial relationship was found. Actually, the more complete study mentioned above made it possible to account for these relationships in terms of abilities whose generality was established by correlation with many other measures, obtained from several hundred individuals. Chinning and pushups each turned out to involve the ability of *limb strength*. Pushups and sit-ups are each contributed to by *trunk strength*. Hence, there is substantial correlation between pushups (which required both these abilities) and each of the other two tasks. The zero correlation between chinning and sit-ups is attributable to the fact that chinning requires only limb strength, whereas sit-ups is affected only by trunk strength. Although a somewhat oversimplified account, this example illustrates how the psychologist, using the technique of correlation, is able to separate and identify categories of man's basic abilities.

THE DISTRIBUTION OF ABILITIES

A common error in describing people's abilities is to use qualitative, categorical terms. Most people tend to classify other people into types. Thus, individuals are thought of as being bright or dull, creative or not creative, athletic or unathletic. The implication in each of these pairs of terms is that a man falls in one of the two categories. But such sharp qualitative distinctions do not fit with the facts. People do not fall into clearly differentiated types. Careful measurement shows that people are distributed along a continuous scale in every human trait.

Thus, individual differences are said to be quantitative rather than qualitative. Even such traits as blindness, or color-blindness, or deafness are often a matter of degree, although for various reasons people are classified as blind or not blind, and deaf or not deaf. Figure 5.9, for example, shows how 835 men were distributed in the scores they achieved on a test

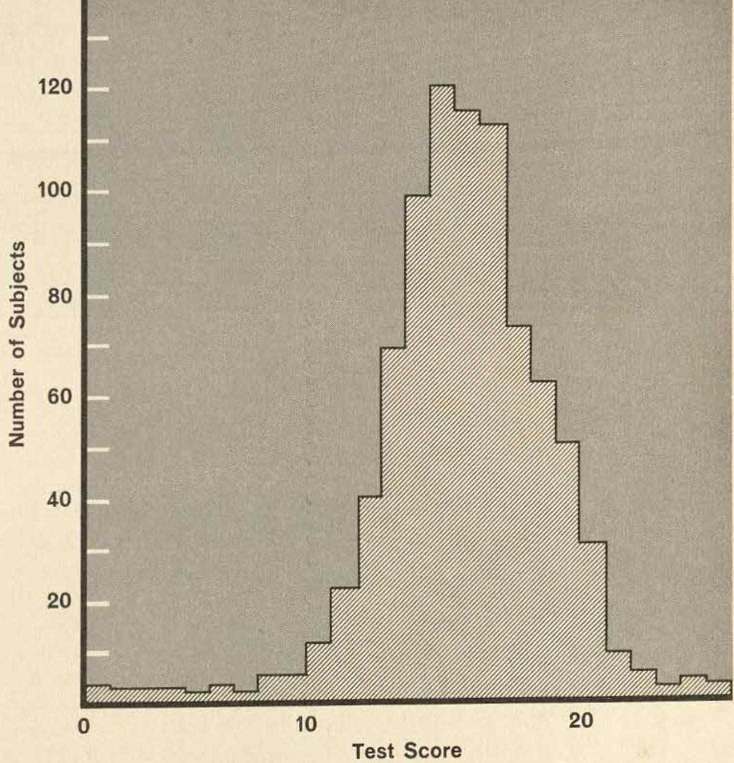


FIGURE 5.9. *Distribution of scores on a test of color-blindness. (After Houstoun, R. A.,* Vision and color vision. *New York: Longmans, 1932)*

of color-blindness. It is clear from these scores that color-blindness is a matter of degree, although, for practical purposes, we may classify those who score below a certain score as "color-blind."

Given the fact that individual differences in ability are quantitative and a matter of degree, there remains the question of how these different degrees are actually distributed among large numbers of people. In other words, if we take measurements of how people score on a particular ability, do we find an equal number of people scoring at all points on the scale?

The Normal Curve

If we measure any one of man's abilities, we find that this ability is distributed in a highly similar manner to any other ability, provided we have measured individuals selected at random so that they are representative of the general population. As a matter of fact, the form of this distribution is frequently the same whether one measures abilities, physical traits, or personality characteristics. Thus, the distribution of measurements of height, reaction time, honesty, visual acuity, aggressiveness, lung capacity,

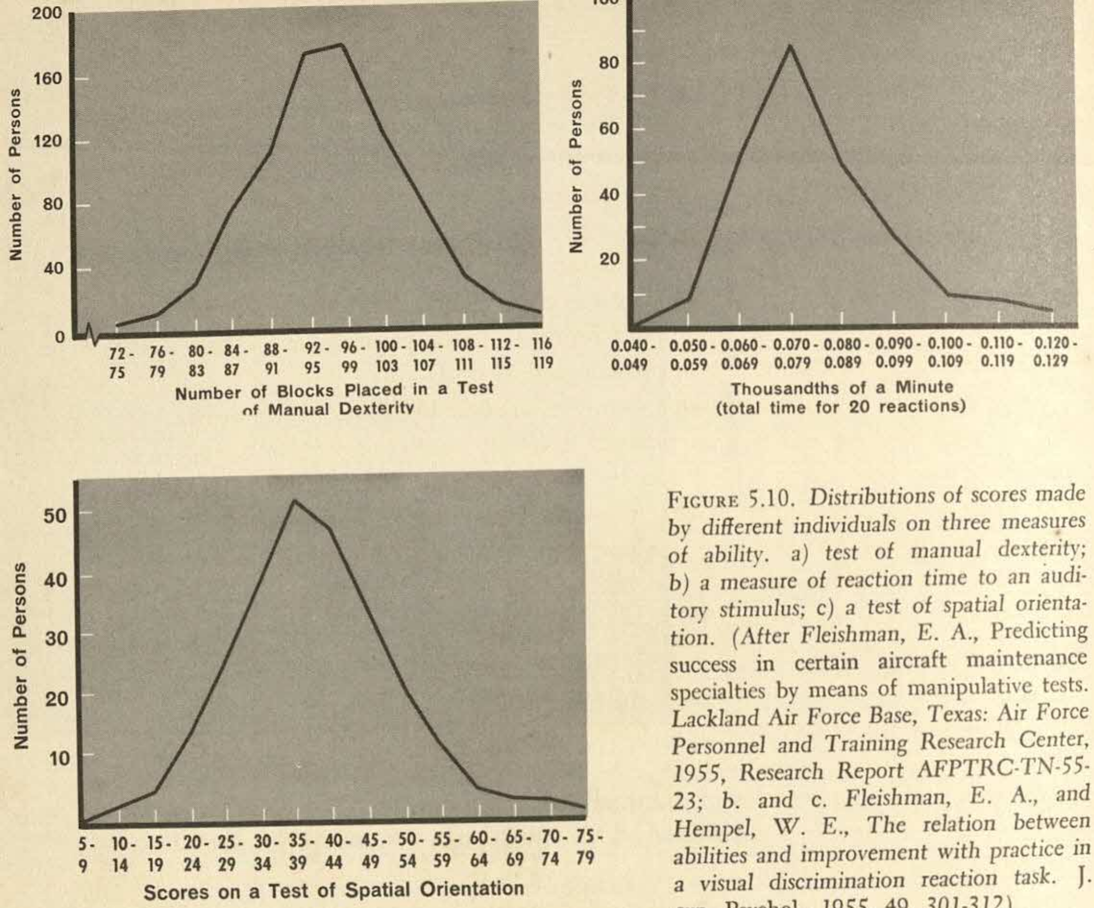


FIGURE 5.10. *Distributions of scores made by different individuals on three measures of ability. a) test of manual dexterity; b) a measure of reaction time to an auditory stimulus; c) a test of spatial orientation. (After Fleishman, E. A., Predicting success in certain aircraft maintenance specialties by means of manipulative tests. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1955, Research Report AFPTRC-TN-55-23; b. and c. Fleishman, E. A., and Hempel, W. E., The relation between abilities and improvement with practice in a visual discrimination reaction task. J. exp. Psychol., 1955, 49, 301-312)*

or motor coordination has the same characteristic form. Let us now examine this distribution more closely.

The statistical method by which such facts come to light is the *frequency distribution* and its graphic representation. Basically, this method involves tabulating the different scores achieved by a large number of people and grouping the number of people who achieve each score, or in other terms, tabulating the frequency with which each score is attained. Figure 5.9 is an example of this kind of representation, called a *histogram*. Most often, we do not actually tabulate each individual score, since the range of possible scores is often quite large. Instead, scores are grouped into *class intervals*, for example, scores falling between 5-9, 10-14, 15-19, etc. Once we have the data tabulated in this way we can represent them graphically and observe the shape of our distribution. Figure 5.10 indicates how this may be done in a form called a *frequency polygon*. In a histogram, the number of cases in each class interval is indicated by the height of each column; in the frequency polygon, number of cases is plotted as a point.

The characteristic shape of the distributions of scores for various ability measures is easy to see. First, the majority of people cluster in the center of the range, and as the extremes are approached, there is a gradual and continuous tapering off. Second, the curves show no gaps or breaks. In other words no classes can be found that are clearly qualitatively separate. Third, the curves tend to be bilaterally symmetrical, with the two halves nearly identical. This distribution is familiarly called the *normal curve* and is the type most commonly found in the measurement of individual differences in ability or other psychological traits.

Figure 5.10 a through c presents examples of such distributions for measures of such diverse abilities as *manual dexterity*, *spatial orientation*, and *reaction time*. One thing which can be noted in these distributions, aside from their general similarity, is that those based on the largest numbers of subjects are generally more regular and approach the theoretical "normal curve," which is shown in its ideal mathematical form in Figure 5.11. A distribution closely approximating this normal form, based upon actual data from a finger dexterity task, is shown in Figure 5.12. As indicated earlier, the generality of the normal curve extends to other human traits as well. For example, Figures 5.13 a through c show respectively the distributions for measures of height, visual acuity, and a personality trait (*ascendance-submission*). Even measures of "normal" body temperature taken from a large number of people have this characteristic shape. Thus, even though 98.6° F is considered normal, it is only normal in a statistical sense; that is, most people tend to maintain this body temperature but there is still some variation from person to person around this average.

There can be no guarantee that all measures of human traits or abilities

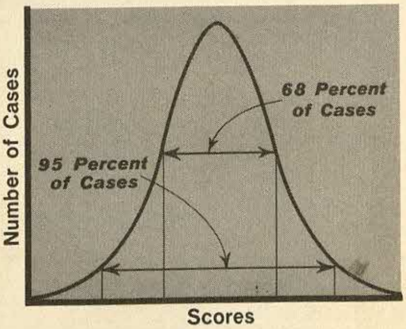


FIGURE 5.11. *The normal curve.*

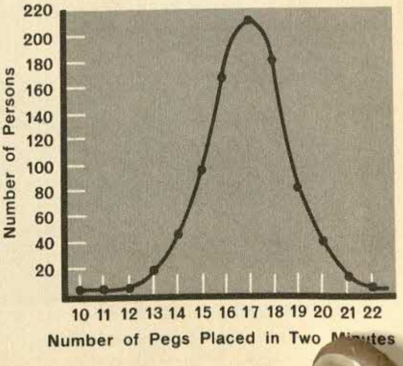


FIGURE 5.12. *Distribution of scores on a test of Finger Dexterity. The curve has been rounded, to conform to the "ideal" curve, but the points represent actual data obtained for 835 subjects. (Data from Fleishman, E. A.,* Predicting success in certain aircraft maintenance specialties by means of manipulative tests. *Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1955, Research Report, AFPTRC-TN-55-23)*

will produce an approximation of the normal curve. However, marked departures from this distribution are signs that closer investigation is warranted to discover the reasons. We shall describe here two different kinds of deviations from "normality." Figure 5.14a shows the distribution of scores obtained on a dynamometer—a device for measuring strength of hand grip. It can be seen that this distribution departs markedly from the theoretical normal curve. There seem to be two "peaks" instead of one. This type of distribution is called a *bimodal* distribution. Closer examination of the measures, and the conditions under which they were obtained, showed that this sample really involved two groups, one of boys and the other of girls. If we plot these hand-grip scores for each group we get the two normal distributions shown in Figure 5.14b. Hence the bimodal distribution is accounted for in a reasonable fashion. Another departure from normality is indicated by Figure 5.15a. This figure represents scores on a test of rhythm discrimination. Here we see a definite piling up of scores at one end of the distribution. This type of deviation from normality is called a *skewed* distribution, displaying a peak near one end and a long tail on the other. In the present example, a disproportionate number of people attained high

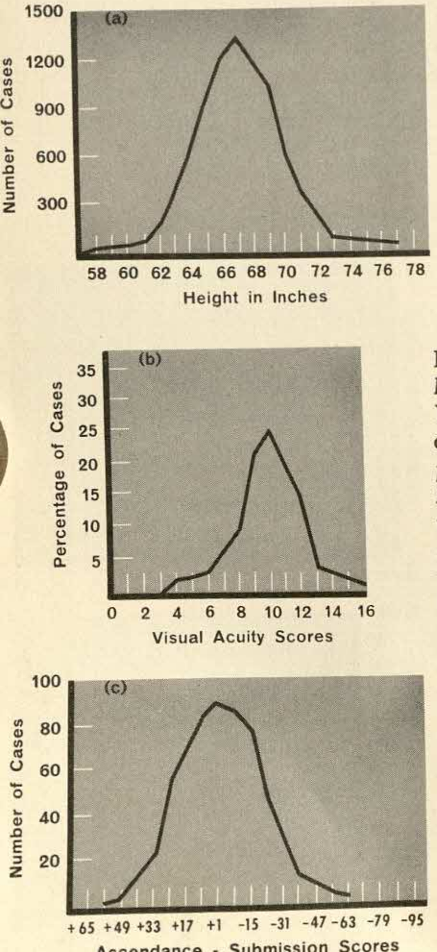
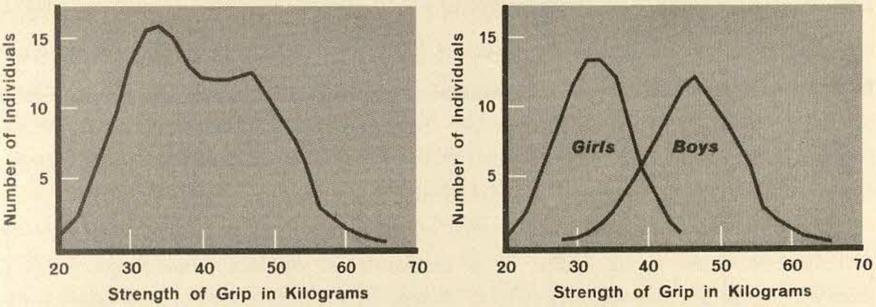


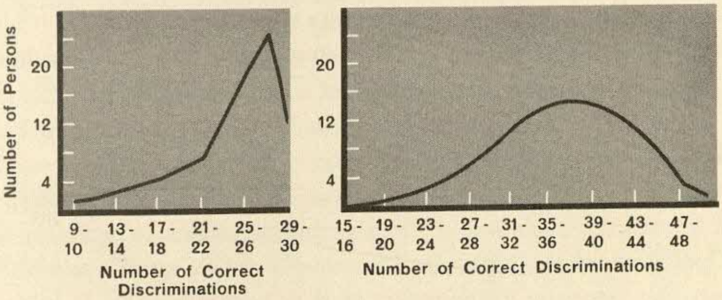
FIGURE 5.13. *The distribution of individual differences for three human traits: a) Heights of 8,585 English-born men. (After Yule, B. U., and Kendall, M. A., An Introduction to the theory of statistics. London: Griffin, 1949); b) Visual acuity of 226 persons. (After Anastasi, A., Differential psychology. New York: Macmillan, 1958; data from Tiffin and Wirt); c) Scores of 600 women on the Allport Ascendance-submission personality test. (After Ruggles, R., and Allport, G. W., Recent applications of the A-S reaction study, J. abn. and soc. Psychol., 1939, 34, 518-528)*



(a)

(b)

FIGURE 5.14. *a) A bimodal distribution of hand-grip scores (boys and girls combined). b) Distribution of hand-grip scores plotted separately for boys and girls. (Data from Jones, H. E.,* Motor performance and growth. *Berkeley: University of California Press, 1949; After Hilgard, E. R.,* Introduction to psychology. *New York: Harcourt, Brace, 1957)*



(a)

(b)

FIGURE 5.15. *a) An example of a skewed distribution of scores on a test of auditory rhythm discrimination. b) The distribution of scores when more difficult discriminations were added to the test. (After Fleishman, E. A., and Friedman, M. P.,* The development of the Air Force aural code test. *Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1957, Research Report AFPTRC-TN-57-131)*

scores. Figure 5.15b indicates what happened when more difficult items were added to the test. The new distribution became more nearly normal. Apparently, much of the skewness was due to inadequacy of the original discrimination test, in that it did not allow the individual differences between people to show themselves properly. The true differences in ability that were really there were not measured by the original test. Thus, departure from a normal distribution may result when something is wrong about the sample of people tested, or when faulty measurement techniques are used. Of course, in other cases the distribution of abilities may actually be non-normal.

Describing Individual Differences

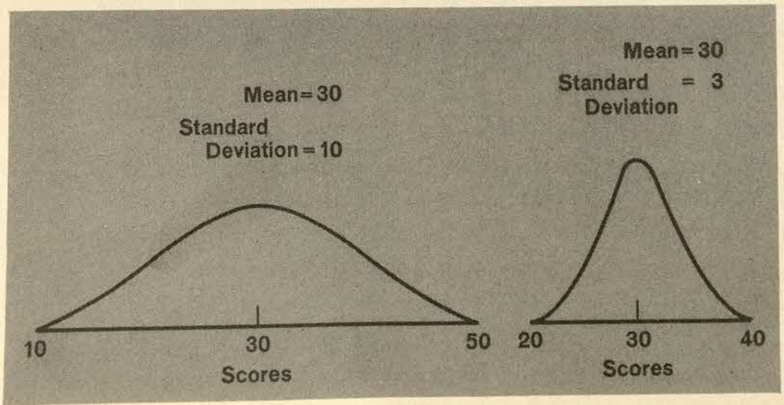
We have mentioned a number of statistical procedures and terms used to characterize individual differences. Thus, the frequency polygon, histogram, and bar graph help reduce the data at hand to a more concise, meaningful picture. We may use terms like *bimodal* or *skewed* to depict gross departures from the normal distribution.

One of the most generally useful ways of describing scores representing ability measures is in terms of a measure of *central tendency*. Such a measure reduces any distribution of scores to a single score which represents the group as a whole. The three most commonly used measures of central tendency are the *mean*, the *median*, and the *mode*. The best known of these is the *mean* (or *average*), which is obtained by adding all the scores and dividing the sum by the number of cases. The *median* is the middle score when all scores are listed in order of size. In other words, half of the scores fall above the median, half below it. The *mode*, which is not used as frequently, is simply the score which occurs most frequently. It corresponds to the highest point in the frequency distribution.

In the *normal distribution*, all of these measures of central tendency coincide. In other words, the most frequent score (mode) is also the median as well as the mean. In other kinds of distribution, it may be useful to have more than one of these values available. For example, if the median is higher than the mean, this tells us that there are a disproportionate number of cases toward the high end of the distribution, which is probably skewed with a "tail" toward the low end. An example of this was Figure 5.15a.

From our previous examination of distribution curves, it is apparent that a measure of central tendency does not give us a complete picture of such a curve. For example, Figure 5.16 presents two distributions with the identical mean of 30. Yet, these distributions differ considerably in the amount of "scatter" or *variability* around this mean. In one distribution, practically everyone gets about the same score; in another distribution a

FIGURE 5.16. *Two distributions with the same mean, but with different amounts of variability.*



number of people depart markedly from the average. *Measures of variability* are the statistics used to describe the degree of scatter.

The most obvious measure of variability is the *range*. We might characterize the first distribution in Figure 5.16 as having a mean of 30 and a range of 40, and the last distribution as having a mean of 30 and a range of 20. This certainly gives a more complete summary of these distributions than would be the case if only means were known. However, the range is not the best measure of variability since it does not take into consideration how the scores between the extremes are distributed. Not only that, but one extremely high or extremely low case can distort the picture of the distribution as a whole. A more exact measure of variability can be obtained by calculating how much each individual score deviates from the mean and then taking an average of these deviations. This statistic, called the *average deviation*, represents a rather direct way of describing the variability. Table 5.3 shows how this may be calculated for two different groups.

TABLE 5.3

COMPUTATION OF THE AVERAGE DEVIATION

Group A Mean = 30		Group B Mean = 30	
Score minus the mean	*d*	*Score minus the mean*	*d*
50 − 30 =	20	40 − 30 =	10
40 − 30 =	10	35 − 30 =	5
30 − 30 =	0	30 − 30 =	0
30 − 20 =	10	30 − 25 =	5
30 − 10 =	20	30 − 20 =	10
Sum of deviations =	60	Sum of deviations =	30
Average deviation =	$\frac{60}{5} = 12$	Average deviation =	$\frac{30}{5} = 6$

The most common measure of variability is the *standard deviation*. This takes the average deviation one step further. Here, the deviation of each score in the distribution from the mean is squared, the sum of all these squared deviations is averaged, and the square root taken.

The formula for the standard deviation is:

$$S.D. = \sqrt{\frac{\text{sum of } d^2}{N}}$$

It has been found that this gives a more stable value than the average deviation and has some additional desirable mathematical properties. Table

5.4 illustrates the calculation of standard deviations for the scores of Table 5.3. It can be seen that the standard deviations are larger than the average deviation for the same distribution. In other words, the standard deviation includes a greater proportion of the distribution.

TABLE 5-4
COMPUTATION OF THE STANDARD DEVIATION

Group A Mean = 30			Group B Mean = 30		
Score minus the mean	d	d^2	*Score minus the mean*	d	d^2
50 − 30 =	20	400	40 − 30 =	10	100
40 − 30 =	10	100	35 − 30 =	5	25
30 − 30 =	0	0	30 − 30 =	0	0
30 − 20 =	10	100	30 − 25 =	5	25
30 − 10 =	20	400	30 − 20 =	10	100
Sum of $d^2 = 1000$			Sum of $d^2 = 250$		
Average of $d^2 = \frac{1000}{5} = 200$			Average of $d^2 = \frac{250}{5} = 50$		
Standard deviation ($S.D.$) = $\sqrt{200} = 14.4$			Standard deviation ($S.D.$) = $\sqrt{50} = 7.1$		

What does the standard deviation mean once you calculate it? The standard deviation indicates the range around the mean within which approximately ⅔ of the cases fall (the average deviation encompasses the middle half of the scores). Thus, in Figure 5.16a, ⅔ of the cases in this sample fall between 20 and 40, ($M = 30$, $S.D. = 10$), while in Figure 5.16b, ⅔ of the cases fall between 27 and 33.

The importance of knowing the standard deviation as well as the mean may be illustrated as follows. Suppose we know that the score achieved by Joe on a vocabulary test is 36 correct responses; and we know the mean score achieved by a large sample of people is 30. This tells us that Joe is above average on vocabulary. But how much above average? Well, he is six points above average, of course, but this is still not too meaningful. For example, suppose Joe's 36 was achieved in the group represented by Figure 5.16a. We can see that Joe is really quite close to the mean score relative to the rest of the group. On the other hand, if Joe achieved his 36 in the group represented by Figure 5.16b, we see that very few exceeded Joe's score. Joe's performance is much more impressive if the standard deviation of the group is 3 rather than 10. The 36 has meaning only if we know both the mean score of the total distribution and its variability. The commonly used statistical technique for showing an individual's relative standing, independent of the variability of the distribution, is the standard score or Z score. The formula for this is simply $Z = \frac{X - M}{S.D.}$, where X is the individual's score, M is the mean of the scores in the comparison group and $S.D.$ is the standard deviation of the comparison group. As an example, Joe's Z score would be .6 in Figure 5.16a and 2 in Figure 5.16b. Such Z scores also help us to compare the relative standing of an individual on several different abilities.

SOME BASIC ABILITIES AND THEIR MEASUREMENT

Now that we have seen how basic abilities are identified, how they develop, and how they are distributed, it is time to return to a consideration of what they are. In this section we will take a closer look at some of the best known abilities which have been studied, with specific illustrations of how they are measured.

As psychological research on individual differences continues, more areas of ability are being explored and new basic abilities discovered and named. Some areas have been mapped out more completely than others. Moreover, the definitions of many of these abilities will become increasingly precise as research tells us more about the range of tasks to which each ability applies or does not apply.

We shall group the abilities under some of the behavioral functions discussed in Chapter 3, in order to indicate what kinds of functions they support. For example, a particular performance of identification may be facilitated by high degrees of general ability in *perceptual speed* and *visual memory.* A task involving problem-solving may be supported by the general abilities of *reasoning* and *verbal comprehension.* Accordingly, we arrange the most important and best-known human abilities under the kinds of functions to which they have been shown to be related. A given general ability, of course, may be related to a great variety of human activities and jobs. But, presumably, it is most highly related to, and provides support for, some one of the functions we have described in Chapter 3.

Abilities Supporting Discrimination

People differ in their ability to make discriminations. As we have seen, this function depends upon the structures of the receptors, the sensory nerves, and their sensory connections. These *sensory capacities* are basic to many areas of behavior, and we shall describe them in some detail in

Chapter 7. Here, we simply note that individuals differ in their abilities to distinguish slight changes in various dimensions of physical stimuli. In some senses, such as vision, certain discriminations which can be made even by the average person come close to exceeding the capabilities of machines used to present these stimuli. When this happens, of course, the measurement of individual differences in these capacities may be exceedingly difficult. But in most instances the distribution of scores for sensory capacities is readily obtained.

For visual stimuli, the discrimination abilities commonly measured are those pertaining to intensity of light (*brightness*) and to wave length (*color* or *hue*). In addition one can measure differences in discrimination of the wave composition of light of mixed wave lengths (*saturation* or *purity*). Tests of *color-blindness* often depend on the fact that the color-blind individual tends to react on the basis of brightness differences rather than color differences. A well-known measure of visual discrimination is *visual acuity,* which refers to the fineness of discrimination of differences between adjacent light and dark areas. The familiar *Snellen Chart,* which presents printed rows of black letters of decreasing size, is frequently used to measure acuity. (See Figure 5.17.)

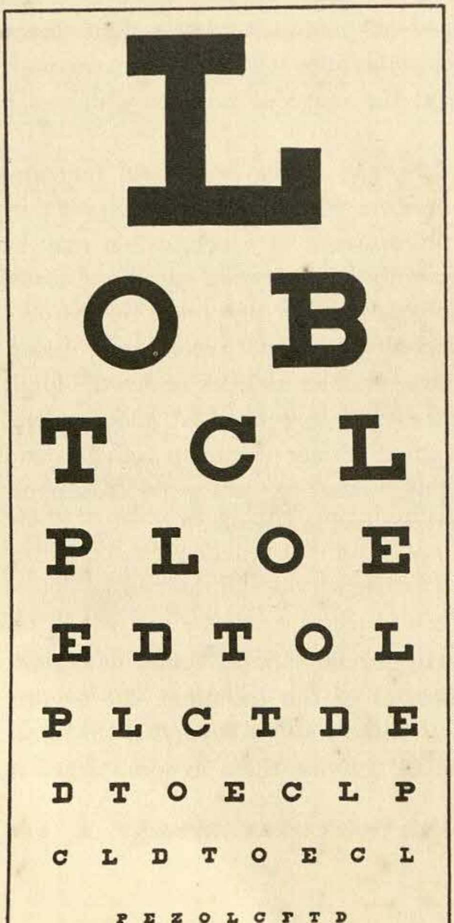


FIGURE 5.17. *A typical Snellen chart for measuring visual acuity. The Snellen test measures acuity from the visual angles subtended by the letters. A score of 20/40 means that the individual can read at 20 feet only those letters an average person can see at 40 feet.*

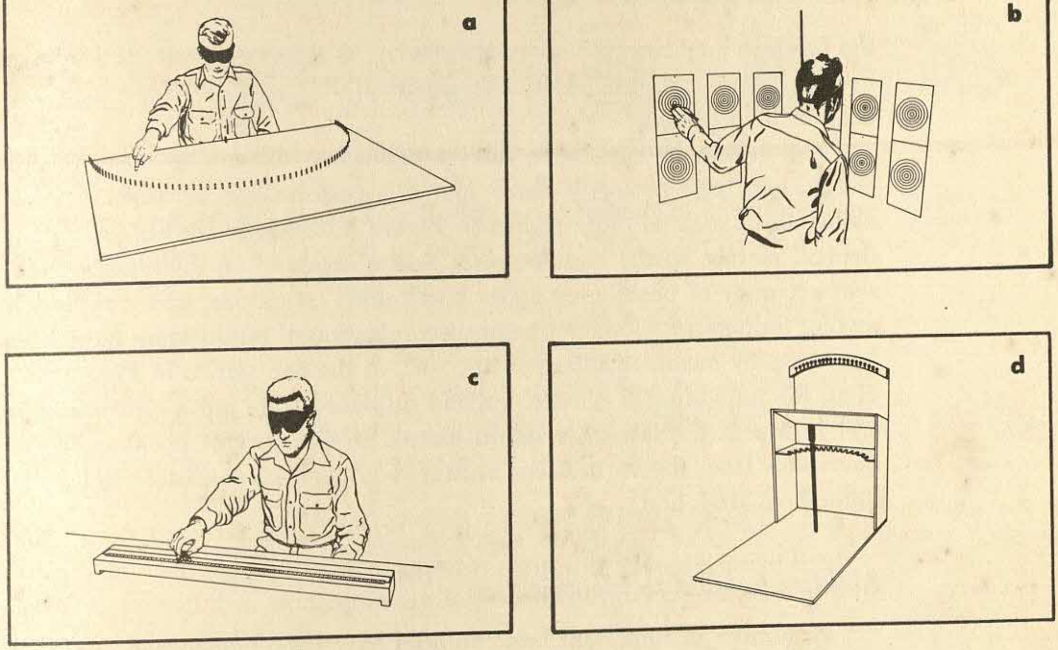


FIGURE 5.18. *Measures of the accuracy of positioning movements, which reflect differences in kinesthetic discrimination. In these tests the blindfolded subject must a) reach a certain peg or b) mark a certain target, in response to verbal instructions. In tests c) and d), respectively, he reproduces certain movements with a knob or a stick control. (From Fleishman, E. A., An analysis of positioning movements and static reactions,* J. exp. Psychol., *1958, 55, 13-24).*

In the case of hearing, discrimination abilities are often measured for intensity of pure tones (*loudness*) as well as for frequency of tones (*pitch*). The discrimination of *duration* of short tones or clicks may also be determined.

Individual differences in visual and auditory capacities often have important practical consequences in human occupations. For example, the degree of proficiency achieved by an inspector on an assembly line may depend significantly on his visual acuity. Likewise, the successful operation of Navy sonar equipment may demand relatively high degrees of auditory discrimination abilities.

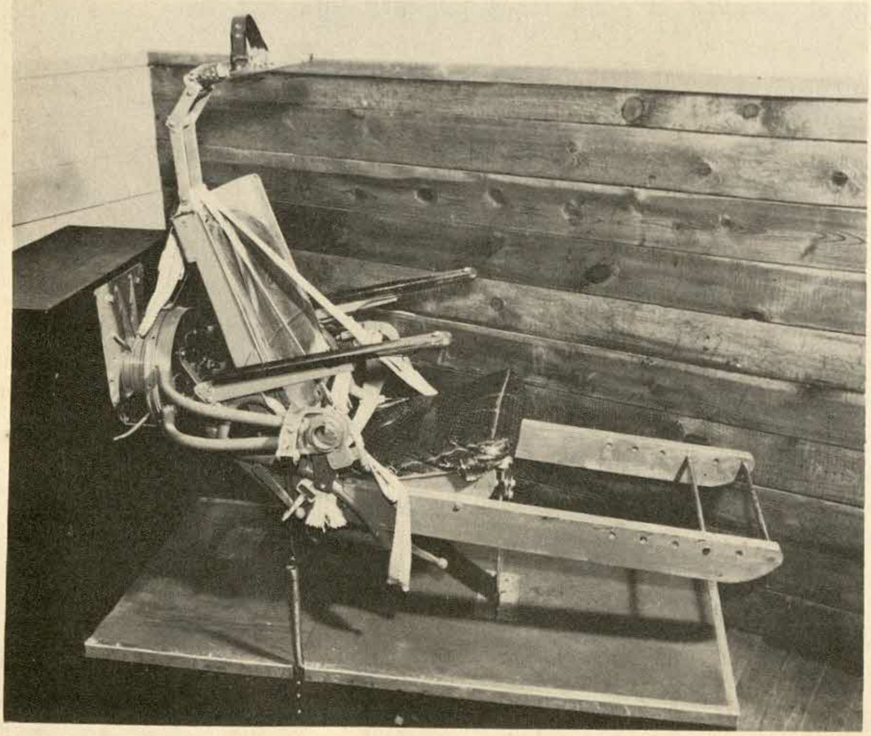
Individual differences in discriminations of stimuli for the other senses have seldom been systematically measured, presumably because of their lesser practical importance. This does not mean that practical consequences may not be discovered in the future. Discrimination abilities can be determined for the sense of smell, for taste, and for skin sensitivity (as will be mentioned in Chapter 7); the first two may have importance for certain jobs in the perfume and wine industries, respectively. There is also increasing interest in relating skin (tactile) sensitivity to certain practical tasks. There is some evidence, for example, that code sent as vibrations against the forearm may be received quite rapidly. As the equipment used by man becomes more complex, additional individual differences in these areas may need to be explored.

Differences in kinesthetic discrimination are difficult to measure precisely, but they probably enter into the performance of certain motor ability tests such as those shown in Figure 5.18, where the subject has to depend mainly on the muscle sense. Scores obtained on these tasks represent accuracy of positioning under blindfolded conditions, and vary widely among individuals. Differences in discrimination of equilibrium have been measured by means of tilting chairs, such as the one shown in Figure 5.19. Here the individual is blindfolded and displaced from an upright position, and in repeated trials must return himself to the upright position. When deviations from the vertical are measured in degrees, consistent individual differences are found.

Abilities Related to Identification

A number of important basic abilities have been named and described which support various specific tasks involving the behavioral function of identification. Most of these are visual abilities; they are measured by tests

FIGURE 5.19. *The tilting-chair apparatus for measuring discrimination involving equilibrium. (From Fleishman, E. A., Perception of body position in the absence of visual cues, J. exp. Psychol., 1953, 46, 261-270)*



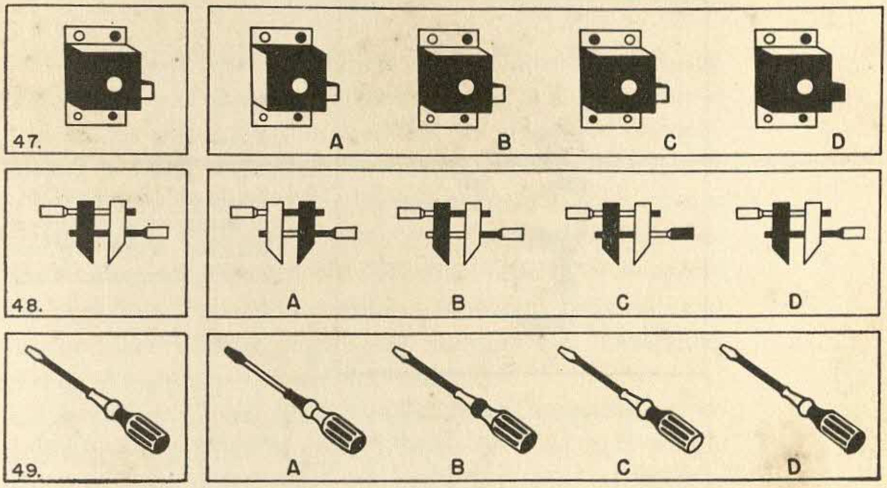


FIGURE 5.20. *Items from a measure of perceptual speed. The subject determines, as rapidly as possible, which figure on the right is like the figure on the left. (Adapted from the* General aptitude test battery, *U. S. Department of Labor)*

that require the identification of objects, patterns, letters, numerals, and shapes.

PERCEPTUAL SPEED. The central features of this ability are the rapidity and accuracy with which individuals can or cannot identify small differences in visual details and configurations.[7] Measures of this ability may require the individual to go down a list of pairs of names or numbers and check those which are the same. Another kind of task, pictured in Figure 5.20, presents a series of problems in which the individual must pick out of a number of highly similar figures the one which is the same as a comparison figure. Still another test requires the individual to scan a series of dials (printed in a test booklet) and make accurate readings. Practically anyone can perform tasks such as these if given unlimited time. The emphasis of this ability measure, however, is on the speed with which detailed visual material can be scanned accurately. Individual differences in this ability are related to success in many performances ranging from those in clerical jobs to those of the aircraft navigator.

CLOSURE ABILITIES. These abilities require the individual to identify or recall models, when the stimuli for these are presented in incomplete form. Two "closure abilities" have been identified.[8] The first, called "Speed of Closure" represents the ability to recognize or identify objects from a set of incomplete, apparently disconnected visual representations. In a sense, the individual "unifies" these disparate parts of the picture into an organized identification. An example of measures used to assess this ability is found in Figure 5.21a. At first glance, the drawing in the figure may appear like a set of disconnected spots. People often report, however, that suddenly

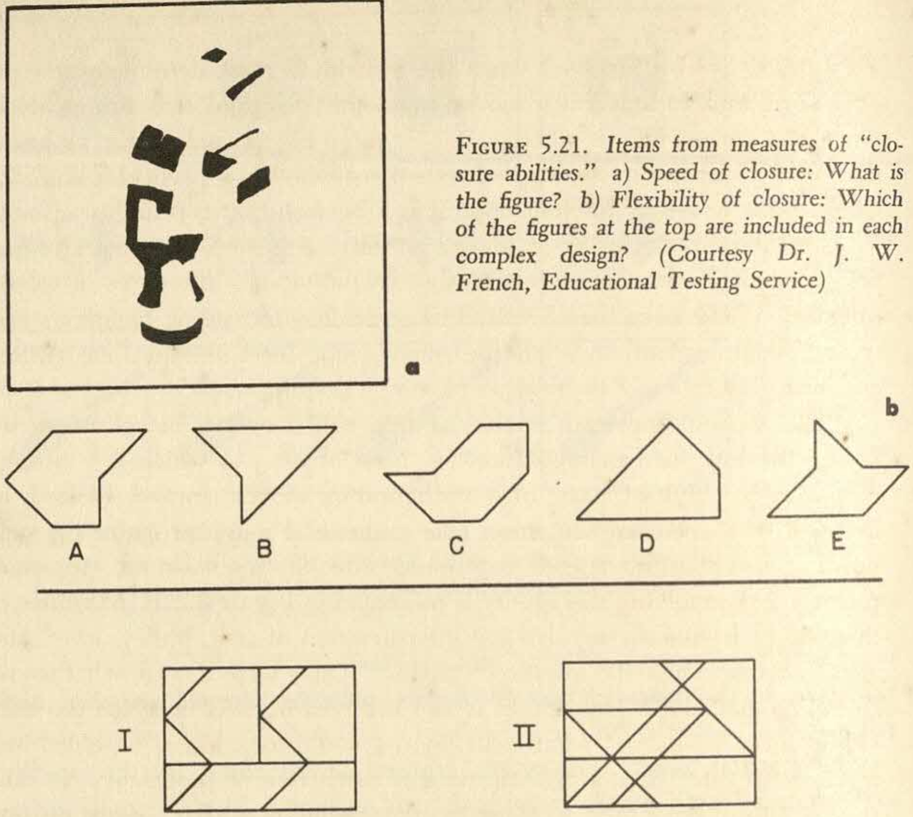


FIGURE 5.21. *Items from measures of "closure abilities." a) Speed of closure: What is the figure? b) Flexibility of closure: Which of the figures at the top are included in each complex design? (Courtesy Dr. J. W. French, Educational Testing Service)*

"closure," or complete recognition, is gained of what the picture represents. Can you identify this one?

A second closure ability, called "Flexibility of Closure," is defined as the ability to identify a particular configuration imbedded in distracting visual material. This ability differs from Speed of Closure in that the individual knows the particular configuration he is looking for. Measures of this ability involve tasks such as those represented in Figure 5.21b. It is of interest that the first closure ability contributes to success in receiving Morse Code. Apparently the ability to "identify" and "unify" the appropriate stimuli extends to tasks which present a stream of auditory signals as well as to those using visual stimuli.

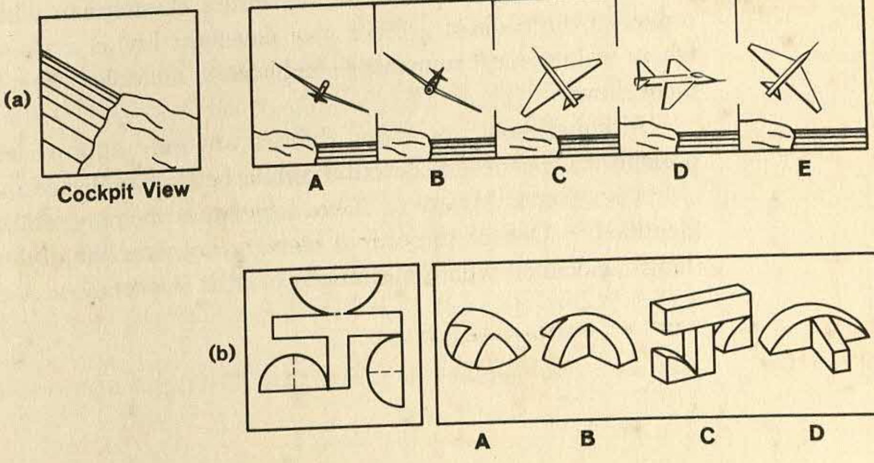
SPATIAL ABILITIES. Another class of ability involves the identification of spatial positions in two or three dimensions. Sometimes, the tests used to measure this ability require the individual to identify his own position in space, sometimes the position of other objects. Two primary spatial abilities have been identified.[9] One of these, called *spatial orientation*, involves the ability to comprehend the arrangement of a visual stimulus pattern, primarily with reference to the location of the individual himself. Tests of this ability often ask, "What position are you in, if the situation is like this?"

This ability is also involved when the individual must determine how an object will look to him if it is moved to another position. It is also involved when the person judges whether one or more objects are higher or lower than others; farther or nearer than others; or whether a particular object is to the right or left of another one. It can be seen that this ability extends to many important classes of human activity. Figure 5.22a illustrates one type of item used to measure this ability. Individual differences in spatial orientation have been found related to proficiency in reading blueprints and wiring diagrams, airplane piloting, radar-scope interpretation, navigation, and to the operation of many types of complex equipment.

The second important spatial ability, called *spatial visualization*, involves the imagined manipulation of visual objects, in which it is usually necessary to think of parts of a configuration moved, turned, twisted, or inverted in a specified sequence. The individual must recognize the new position, location, or changed appearance after the modification. An example of a task involving this ability is presented in Figure 5.22b. Measures of this ability frequently involve the interpretation of belt, pulley, lever, and gear systems. There the question posed is, "If this were moved, what would this other part do?" This ability is also involved in tasks in which the individual must "visualize" what solid figures would look like if unfolded and pressed flat, etc. Spatial visualization is predictive of proficiency on such superficially diverse tasks as those in engineering, dentistry, navigation, and the trouble-shooting of complex electronic equipment.

AUDITORY IDENTIFICATION ABILITIES. Several important abilities have been isolated which are confined to auditory tasks.[10] One of these, called *auditory rhythm discrimination*, involves the ability to identify auditory signals which differ in their rhythmic patterns. This ability appears general

FIGURE 5.22. *Items from measures of two spatial abilities. a) Spatial orientation. (From Guilford, J. P., and Lacey, J. I. (Eds.), Printed classification tests, AAF Psychology Research Program, Research Report No. 5. Washington, D. C.: U. S. Govt. Printing Office, 1947); b) Spatial visualization. (Adapted from the General aptitude test battery, U. S. Department of Labor)*



to auditory tests regardless of the kind of auditory signals involved (e.g., tunes, beats, voice, Morse code signals). A typical measure of this ability presents the subject with a long series of rhythmic patterns presented in pairs. For each pair, the subject must decide if the second pattern is the same or is different from the first pattern. A different test requires the subject to identify whether or not a short series of musical notes is contained in a longer series of notes. A second auditory ability, *auditory perceptual speed*, represents the ability to identify an auditory signal under highly speeded conditions. In measures of this ability, the individual must respond almost immediately to the auditory signal or he will miss the next signal. One of the best measures of this ability is a test in which a whole string of numbers is called out in rapid succession, and the subject tries to keep pace by marking the numbers off on a printed answer sheet. It is of interest that this ability and auditory rhythm discrimination have a very low correlation with each other; in other words, an individual can be high on both, low on both, or high on one and low on the other. Yet both are related to success in Morse code learning. If we know a student is high on both abilities, we can make a good prediction about his later proficiency as a radiotelegrapher. Incidentally, scoring high or low on this ability is unrelated to the (visual) perceptual speed ability described earlier.

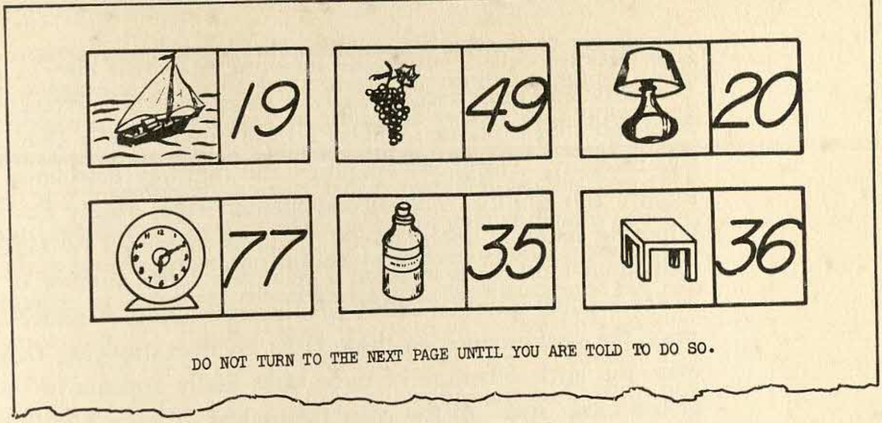
Memory

The different memory functions are supported by a small group of abilities.[11] These abilities are closely related to the individual's performance on tasks that require him to retain certain kinds of information, models, or concepts.

The memory abilities are related to what we have called elsewhere the "storage" capacity of the behavior system. Research indicates that people differ not only in their over-all "storage" capacity, but also in the kinds of things they can store. Moreover, people who can recall relatively meaningless verbal materials stored for a very short time (a few minutes) may not be the ones who are best at recalling meaningful material stored for longer periods. The highly proficient short-order counterman who calls back his orders to the cook in a diner may never qualify as a waiter at Antoine's, where waiters must remember complicated, multiple orders without writing them down.

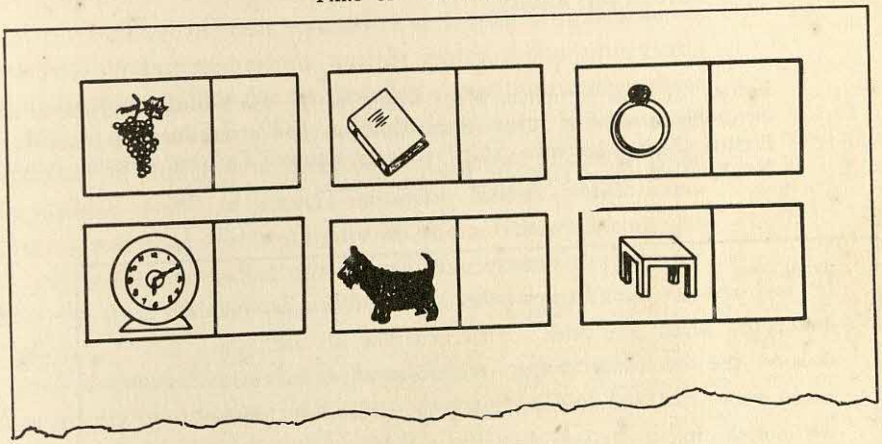
Although some of these abilities are only approximately defined at present, it is possible to describe certain better-established memory abilities.

ASSOCIATIVE MEMORY. Two associative memory abilities have been identified.[12] One of these, *rote memory*, involves the ability to remember things associated where meaning is of little importance. A typical measure



DO NOT TURN TO THE NEXT PAGE UNTIL YOU ARE TOLD TO DO SO.

PART OF "MEMORY" PAGE



PART OF TEST PAGE

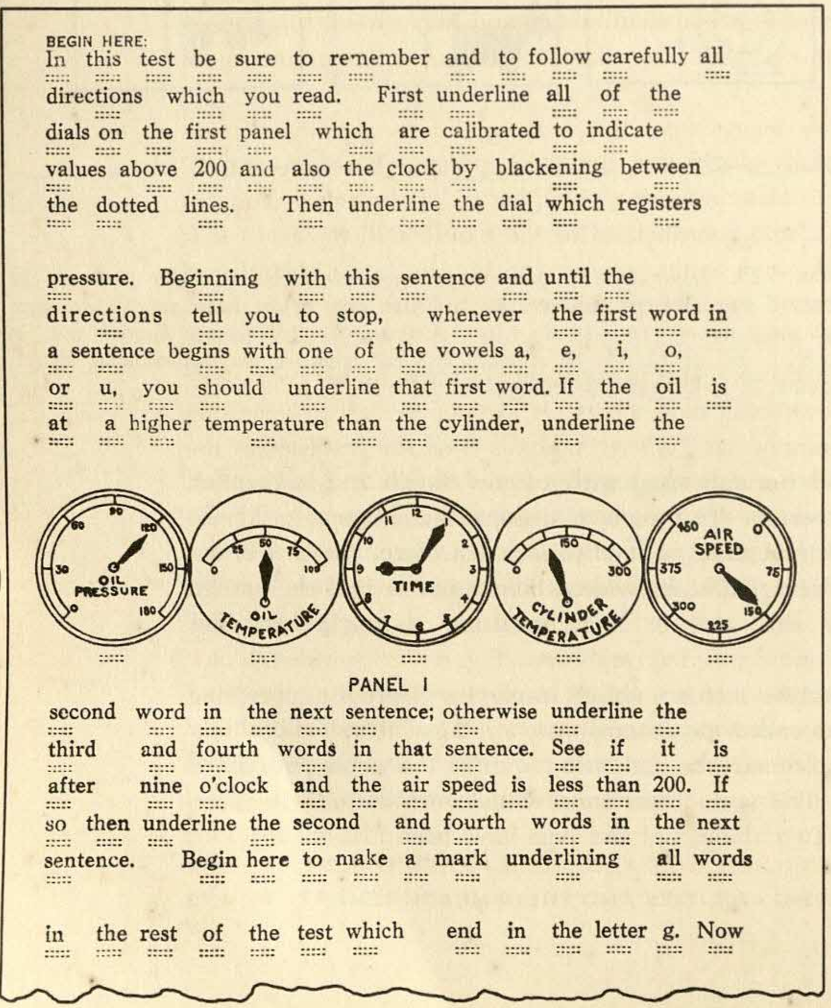
FIGURE 5.23. *Items from a measure of associative memory. Only parts of the "memory" page and test page are shown; hence some of the items on the two pages shown here do not correspond. (After Anastasi, A., The picture number test, in French, J. W. (Ed.), Kit of selected tests for reference and achievement factors. Princeton, N. J.: Educational Testing Service, 1954)*

of this ability presents the individual with a series of first and last names. Later, when the last names are presented to him in a different order, he writes the appropriate first name in front of each last name. Another example is presented in Figure 5.23. Individual differences in learning foreign language vocabulary lists are, in large measure, a function of this ability.

The second associative memory ability involves memory for conceptual material and has been called *meaningful memory.* Measures of this ability involve sentence completion tasks, and tasks requiring the naming of related words and synonyms in response to particular stimulus words.

MEMORY SPAN. Two abilities of this type have been identified.[13] One is sometimes called *immediate memory,* in which after a single exposure the individual must recall, totally, a series of digits, letters, or things to do. Remembering a phone number, license number, or a shopping list falls in this category. Telephone operators and highway patrolmen would seem to require this ability. The second memory-span ability has been given the imposing name of *integration I.* This is measured by tasks in which the individual must keep in mind a relatively large number of detailed rules. There is some question about whether this ability is really memory ability, since the performance on these tasks involves *applying* these rules. However, the critical feature of these tasks really appears to be one's memory of the total "span" of the rules themselves. Figure 5.24 illustrates a measure of this ability.

FIGURE 5.24. *A portion of a test which requires the retention and use of an increasing number of rules. (From Guilford, J. P., and Lacey, J. I. (Eds.),* Printed classification tests, *AAF Psychology Research Program, Research Report No. 5. Washington, D. C.: U. S. Govt. Printing Office, 1947)*



BEGIN HERE:

In this test be sure to remember and to follow carefully all directions which you read. First underline all of the dials on the first panel which are calibrated to indicate values above 200 and also the clock by blackening between the dotted lines. Then underline the dial which registers

pressure. Beginning with this sentence and until the directions tell you to stop, whenever the first word in a sentence begins with one of the vowels a, e, i, o, or u, you should underline that first word. If the oil is at a higher temperature than the cylinder, underline the

PANEL I

second word in the next sentence; otherwise underline the third and fourth words in that sentence. See if it is after nine o'clock and the air speed is less than 200. If so then underline the second and fourth words in the next sentence. Begin here to make a mark underlining all words

in the rest of the test which end in the letter g. Now

VISUAL MEMORY. This kind of memory ability appears to require retention of exact substance or content of visually presented materials. It is related to the function of identifying in terms of models and reinstating these identifications at a later time. Picking out a face in a crowd as one seen previously, or recognizing an exact color, may fall in this category. This ability has sometimes been called *photographic memory* ability. Measures of it frequently require the subject to view a picture and then to reproduce, recognize, or describe certain features in the absence of the picture.

Motor Abilities

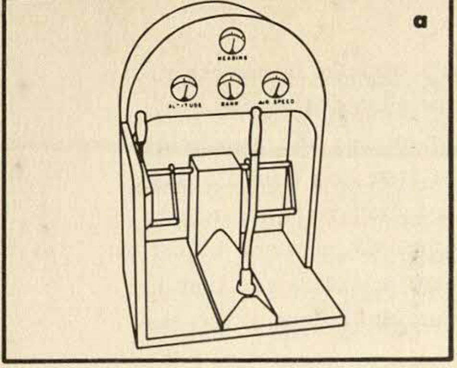
A relatively large number of basic motor abilities, which contribute to the learning and performance of various specific motor skills, have been identified.[14] Most of these abilities are narrower in scope than many other types of basic abilities. In other words, a particular motor ability may facilitate performance in only a few specific tasks. There is no general motor ability, or athletic ability, or general dexterity. Rather, within each of these areas there are several different motor abilities. However, some of the abilities are broader in scope than others, and may extend to performances on superficially diverse tasks. Some of the most important motor abilities are as follows:

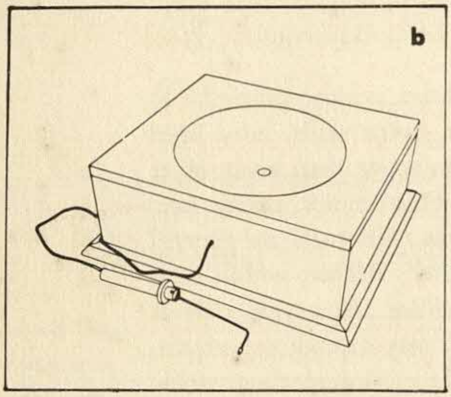
MULTIPLE LIMB COORDINATION. This is the ability to coordinate simultaneously the movements of different limbs, in operating a set of controls. This ability extends to tasks requiring coordination of the two hands, coordination of the feet, and coordination of the hands with the feet. It is best measured by tasks such as that pictured in Figure 5.25a. Measures of this ability are predictive of later proficiency as an airplane pilot, bombardier, and helicopter pilot.

FINE CONTROL PRECISION. This is the ability to make highly controlled, rapid, and precise positioning movements. It extends to skill in operating levers, control sticks, knobs, etc., where emphasis is on the precision of the response. Figure 5.25b presents an example of how the ability is measured.

RESPONSE ORIENTATION. This is, in a sense, a motor response identification ability. The individual must choose and perform the proper response or the proper direction of response, when he has several alternatives available; that is, he must choose the right switch, the right button or pedal, etc., especially under speeded conditions. Figure 5.25c presents a task found to sample this ability. It is involved in varying degrees in operating equipment such as steamshovels, automobiles, airplanes, telephone switchboards, computers, and typewriters.

REACTION TIME. This is the sheer speed with which an individual can





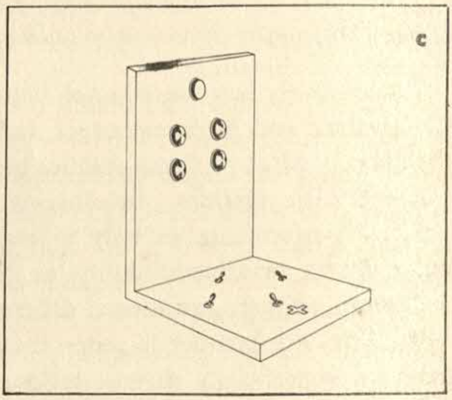
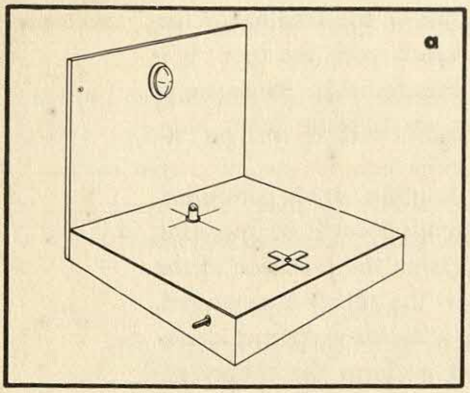
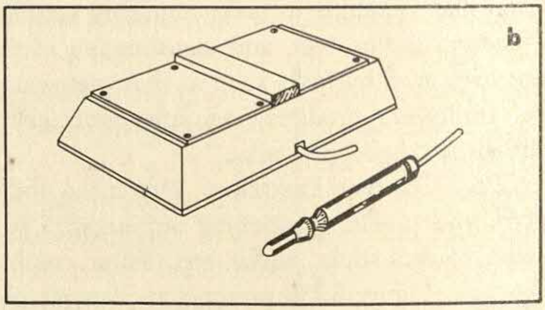


FIGURE 5.25. *Devices used to measure motor abilities. a) Multiple-limb coordination, b) Control precision, and c) Response orientation. a) The subject must keep all the pointers lined up simultaneously by coordinated movements of stick, rudder pedals, and lever control. b) The subject tries to keep the stylus in contact with the target set near the edge of a revolving turntable. c) The subject throws one of four switches in response to rapidly changing light patterns. (From Fleishman, E. A., Dimensional analysis of movement reactions,* J. exp. Psychol., *1958, 55, 438-453)*





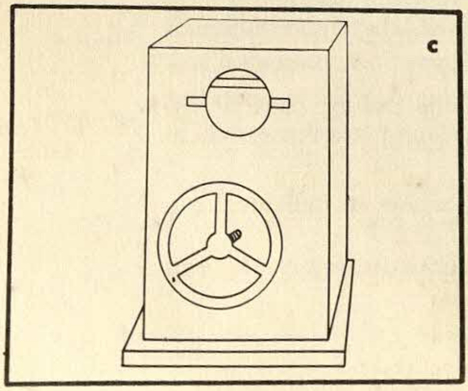


FIGURE 5.26. *Devices used to measure the motor abilities of a) Reaction time, b) Speed of arm movement, and c) Rate control. a) The subject presses the button as rapidly as possible when the light comes on. b) The subject strikes each metal plate, with the stylus, alternating right to left and back as rapidly as possible. c) The subject manipulates a "dampened" control wheel to keep the line in the window centered as it deviates from the center position. (a. and b. from Fleishman, E. A., A dimensional analysis of motor abilities,* J. exp. Psychol., *1954, 48, 437-454; c. from Fleishman, E. A., Dimensional analysis of movement reactions,* J. exp. Psychol., *1958, 55, 438-453)*

react to a stimulus. It is common to tasks involving either visual or auditory stimuli as well as to tasks in which the response is made with the arms, legs, jaws, or other body members. Thus the ability is independent of the particular sense modality or muscle group involved. People who have fast reaction time to light are likely to have fast reaction time to a buzzer. Figure 5.26a shows a typical reaction-time measuring device.

SPEED OF ARM MOVEMENT. The speed with which a gross arm movement can be made regardless of precision or accuracy is another and different ability involving motor speed. Figure 5.26b shows a test of this ability. Studies have shown that this ability may be especially important in establishing the upper limits of proficiency on complex tasks requiring rapid responses of the arms.

RATE CONTROL. This ability is one of making continuous anticipations and motor adjustments to changes in speed and direction of a continuously moving object or target. It is related to proficiency in "tracking" and "pursuit" tasks in which one has to make continual adjustive movements to keep a pointer in a central position as it deviates. Figure 5.26c depicts one representative measure of this ability.

Besides the motor abilities listed, there are two other motor areas which are usually distinguished, called *fine manipulative abilities* and *gross motor abilities*. These areas are separated to indicate the fact that they are quite distinct from each other in terms of correlations between measures of individual differences.[15] In addition, they tend to support different kinds of practical motor performances.

FINE MANIPULATIVE ABILITIES. Three important basic abilities have been identified in this area.[16] *Manual dexterity* is the ability to make skillful, controlled arm-hand manipulations of larger objects. Figure 5.27a shows a representative measure of this. This ability supports performance on tasks requiring tool manipulation, the assembly of large components, and the wrapping of packages. *Finger dexterity* is the ability to make skillful, controlled manipulations with the fingers. Figure 5.27b presents a measure of this ability. It has been found important in small-parts assembly tasks, in wiring electrical circuits and in watchmaking. *Arm-hand steadiness* is measured as the precision with which one is able to make accurate arm-hand positioning movements, where strength and speed are minimized. This ability has been found to extend to tasks involving needle-threading, rifle marksmanship, and stacking small nuts on top of one another. While no study has been carried out, it seems likely that this ability would be useful to people assembling or disassembling components of explosive devices and weapons. Figure 5.27c illustrates a measure of the ability.

GROSS MOTOR ABILITIES. A number of basic abilities in the area of gross motor performance deserve mention.[17] Two of these are *strength of* *trunk* and *strength of limbs*. Parallel abilities of trunk and limb *flexibility* have also been found. Another ability, independent of these, is called *energy mobilization* or "explosive ability," and is exhibited in performances of exerting a maximum of energy at a given moment. Examples of this are throwing a medicine ball as far as possible, jumping as far as possible. *Balance* abilities also appear to be independent. Thus, individuals low in strength or flexibility may or may not score high in tasks such as walking a rail, standing on one foot, etc. *Gross body agility* and *endurance* emerge from research as two additional ability categories in this area. The relation of these gross motor abilities to athletic skill is not well known at the present time, although it seems likely that the relationships must be substantial ones. It has been shown, however, that these abilities do not contribute to a task like flying an airplane, which draws its support to a greater extent from the type of motor abilities described in previous paragraphs.[18]

Conceptual and Thinking Abilities

An important set of abilities pertains to the learning, retention, and utilization of concepts. (We have already mentioned the *meaningful memory* ability, which also contributes to this category of performances.) Frequently these abilities are measured by tasks which require the use of words and numbers. Tasks which require more complex manipulation of

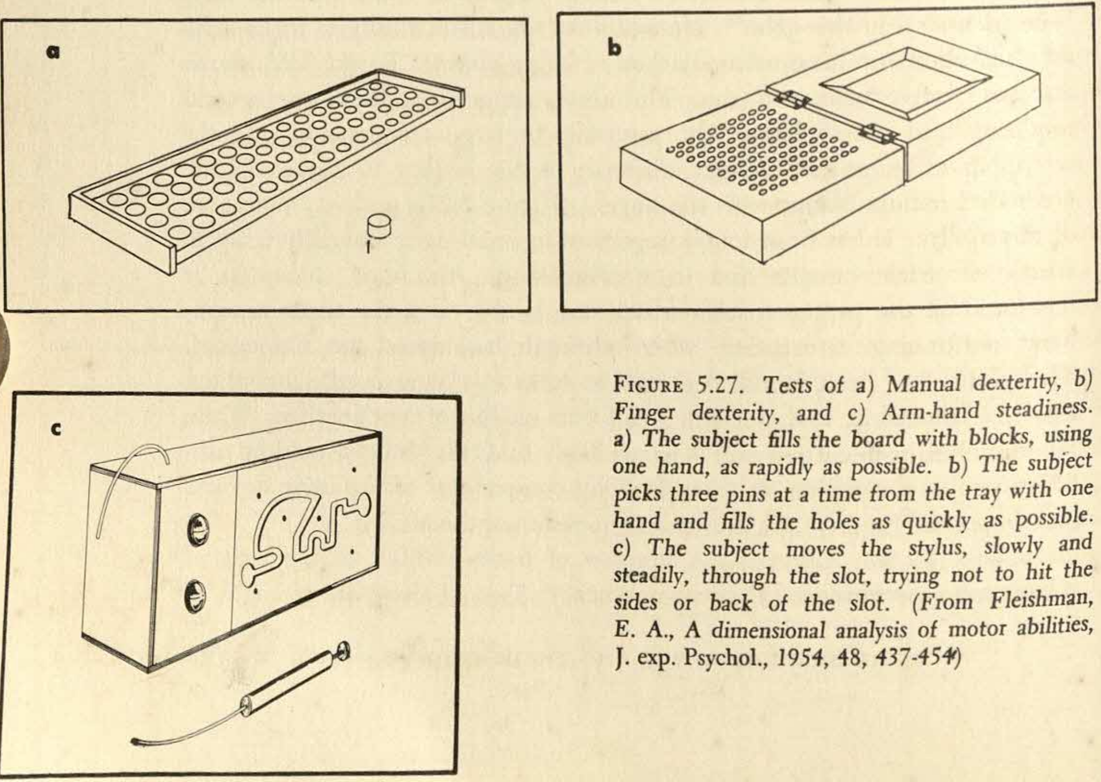


FIGURE 5.27. *Tests of a) Manual dexterity, b) Finger dexterity, and c) Arm-hand steadiness. a) The subject fills the board with blocks, using one hand, as rapidly as possible. b) The subject picks three pins at a time from the tray with one hand and fills the holes as quickly as possible. c) The subject moves the stylus, slowly and steadily, through the slot, trying not to hit the sides or back of the slot. (From Fleishman, E. A., A dimensional analysis of motor abilities,* J. exp. Psychol., 1954, 48, 437-454)

concepts get us into the area of thinking. As in the ability areas discussed previously, the outstanding feature here is that there is no such thing as general "thinking ability." Rather there are several thinking abilities, which relate to individual differences on the great number of intellectual tasks that human beings perform. These abilities have to do with retaining and using class concepts, rules, or relationships. Also involved is the ability to draw comparisons, make generalizations, produce original ideas, produce unique solutions to problems, and evaluate consequences of solutions.

We shall first describe the verbal and numerical abilities that support concept using, and then those which are more closely related to problem-solving and thinking.

VERBAL KNOWLEDGE. This is certainly one of the most important abilities in our culture. It is measured by tests of knowledge and understanding of the English language[19]; individual differences are seen most clearly in the size of the vocabulary that different people possess. However, this ability extends to tasks requiring knowledge of grammatical patterns, understanding of dramatic phrases, comprehension of prose, and other aspects of language. The best measures of this ability are vocabulary tests, tests of reading comprehension, and verbal analogies.

WORD FLUENCY. Although somewhat related to word knowledge, word fluency has been isolated as a separate verbal ability.[20] Word fluency tasks call for a rapid selection and production of words. It appears to involve the speed with which an individual can find words that fit particular categories. It occurs predominantly in such tasks as anagrams, rhyming, and giving words which begin or end with given letters, prefixes, or suffixes.

NUMERICAL ABILITY. This is relatively independent of verbal and other conceptual abilities.[21] It involves facility in handling numbers, in arithmetic operations or otherwise, and is usually measured by arithmetic tests. This ability facilitates performance on tasks involving memory for numbers, counting, plotting on numbered coordinates, finding given numbers and related arithmetical operations. As we shall see, solving complex mathematical problems involves, mainly, other abilities.

CONCEPT FLUENCY. There are differences among people in the availability of concepts, or the readiness with which they can be called forth and applied to given situations.[22] Measures of this ability typically require the individual to write down as many ideas about a given topic as possible. A relatively unrestricted, vague topic (e.g., "a man on a ladder") seems to be all that an idea-fluent person needs, whereas those less fluent will appear handicapped and complain of "a lack of sufficient clues." This appears to be an important ability related to creativity (or inventiveness) of individuals.

DISCOVERY OF PRINCIPLES. A class of abilities concerned with discover-a

Three of the following groups of letters are alike in some way. Mark the one that is different.

C D E F   N O P Q   G F D H   T U V W

b

Write the next two numbers of the series.

2 5 7 12 15 17 ___ ___

−2 0 4 12 28 60 ___ ___

FIGURE 5.28. *Items from thinking tests requiring discovery of principles. (b. After Cureton, E. E., et al.,* The multi-aptitude test. *New York:* The Psychological Corporation, *1955)*

ing relationships and principles has been isolated. Tasks of this type require the individual to make verbal or figural analogies, or to complete a number series. Examples are shown in Figure 5.28. Here, one has to find the principle or rule from information supplied, followed by application of the rule to a new situation. The most difficult aspect of these problems is the discovery of the rule. In general, tasks of this type are carried out by forming and trying out successive hypotheses until one "fits."

GENERAL REASONING. This is one of the more pervasive abilities in this area. It is often measured by mathematics problems such as the following:

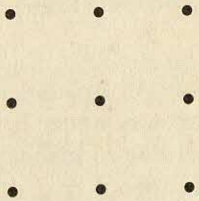
> A plane traveled a certain distance from the base at an average of 225 miles per hour. Engine trouble forced it to return at an average rate of 150 miles per hour. It left at 11:35 A.M. and returned at 12:05 P.M. How far away from its base was the plane when it turned back?
>
> A. 30 miles
> B. 45 miles
> C. 50 miles
> D. 75 miles
> E. 90 miles

This ability has been found to support other types of reasoning performance besides the mathematical, particularly when the critical feature is comprehension of the total structure of the problem.

SEEING IMPLICATIONS AND CONSEQUENCES. Thinking abilities of this type have been called *foresight.* They are related to the kinds of planning activities required of the architect or industrial-layout planner. An example of a measure of this ability presents the individual with a series of questions requiring a decision. The individual is asked what facts he should consider in reaching a decision. For example, a new graduate is offered positions in two different cities. What should be the deciding considerations? List them.

FLEXIBILITY. The ability to discover and apply principles is important, but there are many problem situations which are characterized by drastic and unpredictable shifts requiring new and perhaps unusual solutions. New approaches must be derived; different ways of categorizing and organizing events must be discovered. The ability to do this appears to be more or less independent of other thinking abilities.

Popular puzzle problems frequently require this ability, as shown by facility in solving the following type of task. The task is to connect all the dots, using four straight lines, without lifting the pencil from the paper. Try it.



The correct answer can be arrived at only by freeing oneself of the restriction the average problem-solver is likely to assume in this case.

SYMBOL MANIPULATION. This is the ability to solve problems which require a rigorous manipulation of symbols. An example of such a problem would be the following.

> E means equal to.
> NG means not greater than.
> With this in mind: $x\mathrm{E}y$ and $y\mathrm{NG}z$. From this, which statement can logically be made: $x\mathrm{E}z$, $x\mathrm{NG}z$, etc.?

Obviously, those who deal with mathematical notation probably depend a great deal on this ability.

LOGICAL EVALUATION. This ability involves reasoning from given premises to their necessary conclusions, as in "deduction." Syllogistic tests are considered among the best measures of this ability. For example, individuals may be presented with formal, meaningful syllogisms, in which some of the stated conclusions do not follow correctly from the premises. The task is to indicate which inferences follow correctly from the premises. The subject may be asked, for instance, to judge the reasoning in the following arguments. The statements are false or absurd, but the reasoning may or may not be in error.[23]

	Reasoning is	
	good	poor
All haystacks are catfish. All catfish are typewriters. Therefore, all haystacks are typewriters.	——	——
Red-haired persons always have big feet. All June bugs have big feet. Therefore some June bugs are red-haired.	——	——

Practical Judgment. This is an ability requiring the use of concepts in making sensible decisions, or in giving common-sense answers to practical problems. Tasks requiring this ability may describe a practical predicament, giving all of the most pertinent facts. The individual is required to choose a solution after making some reasonable assumptions concerning the missing facts. Usually, the solution to such problems requires the individual to draw on retained concepts (rules). A typical item from tests of practical judgment follows:

> A uranium prospector is in an isolated mountain area when his jeep breaks down. To make matters worse, it is bitterly cold and a howling blizzard has arisen. According to his map, the nearest point of refuge is a ranger's cabin and telephone at a distance of six miles, following a mountain trail. It is 1:00 p.m. and he starts out for the ranger's cabin. At 2:00 p.m. he arrives at an unmarked fork in the trail. His most practical course of action is to:
>
> (a) Return to the jeep and attempt again to get it started.
> (b) Take the trail which appears to lead in the right direction, and if at 5:00 p.m. the cabin has not been reached, return and take the other fork.
> (c) Remain at the fork until morning.
> (d) Take the trail which appears to lead in the right direction and continue on it until the cabin or the end of the trail has been reached.

Before concluding this discussion of thinking abilities, several cautions should be mentioned. First of all, we have described only what seem to be the most important and representative basic abilities in this area. Perhaps, too, further study of these abilities will lead to their revision as we learn more about their generality. In any case, abilities related to thinking are less distinct than those in certain other areas; that is, they are likely to be more highly correlated with each other. However, the abilities we have described should provide an inkling of some of the complexities of the thinking process, as well as the variety of ways people can differ in these performances. We shall have more to say about thinking and problem-solving behavior in Chapter 9.

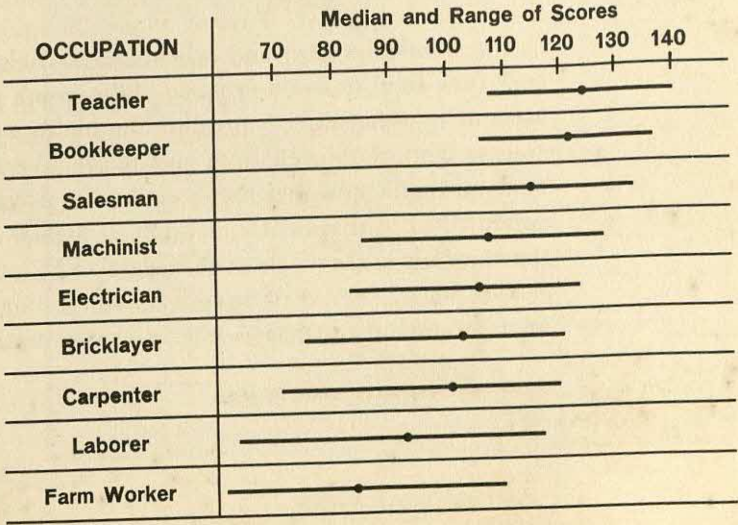
INTELLIGENCE

The student may already have asked, "Where does the notion of 'intelligence' fit into the discussion of abilities?" What about the "I.Q." as a measure of man's general ability? It should be evident from our preceding discussion that man's abilities are too numerous and diverse to be subsumed under a single rubric of "general ability." Intellectual tasks, depending on their nature, bring into play different combinations of the abilities described. It is true, of course, that some persons receive high scores on tests of a great many of the basic abilities, whereas others score relatively low. Most persons, however, reveal an unevenness in their ability pattern in that they score higher on some abilities and lower on others. In this sense, the word "intelligence," as commonly used, tends to oversimplify much of what we now know to be the multidimensional nature of the intellectual processes. It may also be a misleading way of describing individual differences.

Intelligence is usually associated with verbal, memory, numerical, and thinking abilities. Since there is some low, positive correlation between many of these abilities, it is possible to give a composite measure of how different individuals stand on this group of abilities. The term *general intelligence* is commonly used to designate this composite.

Intelligence tests, which are among the most carefully constructed of psychological measures, characteristically provide a single score, such as an I.Q., indicating the individual's "general intelligence level." Different individuals, obviously, may achieve the same total score by excelling in differ-

FIGURE 5.29. *Intelligence-test scores within different occupation groups. The length of line indicates the range of the middle 80 percent of the scores; the dots represent the medians. These data are based on a study of 83,618 enlisted men. (Data from Stewart, N. G., AGCT scores of army personnel grouped by occupation, Occupations, 1947, 26, 5-41)*



ent component abilities. Moreover, intelligence tests are heavily weighted with verbal abilities, and do not cover all the thinking abilities we have just described. But for many practical purposes this composite score is very useful; it has been found highly predictive of success in a variety of human activities. This is not surprising when we realize that tests of intelligence cover several of the most important abilities in our culture. But intelligence tests do not cover a great variety of abilities required in many important areas of human work. For example, the abilities found most important in the complex job of flying an airplane were the spatial, perceptual, and motor abilities rather than those commonly covered by "intelligence" tests.[24]

Intelligence tests have been most successful in predicting subsequent success in school and college (grades in particular courses as well as total grade point average). In fact, many prefer to refer to intelligence as "scholastic aptitude." But this may be too restricted a definition, since there is ample evidence that the kinds of abilities measured by intelligence tests also are related to the individual's success and satisfaction in many job situations. (We shall see some of these results in Chapter 11, which deals with personnel selection.) Of course, the kinds of abilities needed to succeed in school and to succeed in our culture are highly similar. Thus, the amount of education possessed correlates with occupational level, salary, and other criteria of "success." Figure 5.29, for example, indicates the distribution of scores on a standard intelligence test achieved by different civilian occupational groups.

It is just as important to note the range of intelligence scores within each of these groups, as it is to note the medians. For example, note the number of carpenters and laborers who exceed many teachers on this measure. This does not mean that intelligence-test scores do or do not predict success in carpentry, since we do not know if those carpenters with the higher scores are the better carpenters. It means, rather, that many carpenters also have the abilities needed to succeed in teaching careers.

Mental Age and the I.Q.

It should be clear that when the psychologist speaks of a person's intelligence level he is referring to that person's performance as measured by an "intelligence test" covering certain ability areas. Figure 5.30 shows representative items taken from such tests. We may now take a closer look at two fundamental concepts used by the psychologist in measuring intelligence. One of these is the concept of *mental age*. The average child of a given age is able to perform certain tasks, such as obeying simple commands, seeing certain relationships, interpreting pictures, and putting blocks together to form a design after a demonstration. In constructing certain

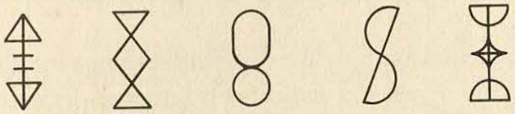
A boy is now three times as old as his sister. In 4 years he will be only twice as old. How many years old is his sister?

1 2 3 4 5

Which word is wrongly spelled?

practical seperate extreme organization appreciate

Which one of the figures does not belong with the other four?



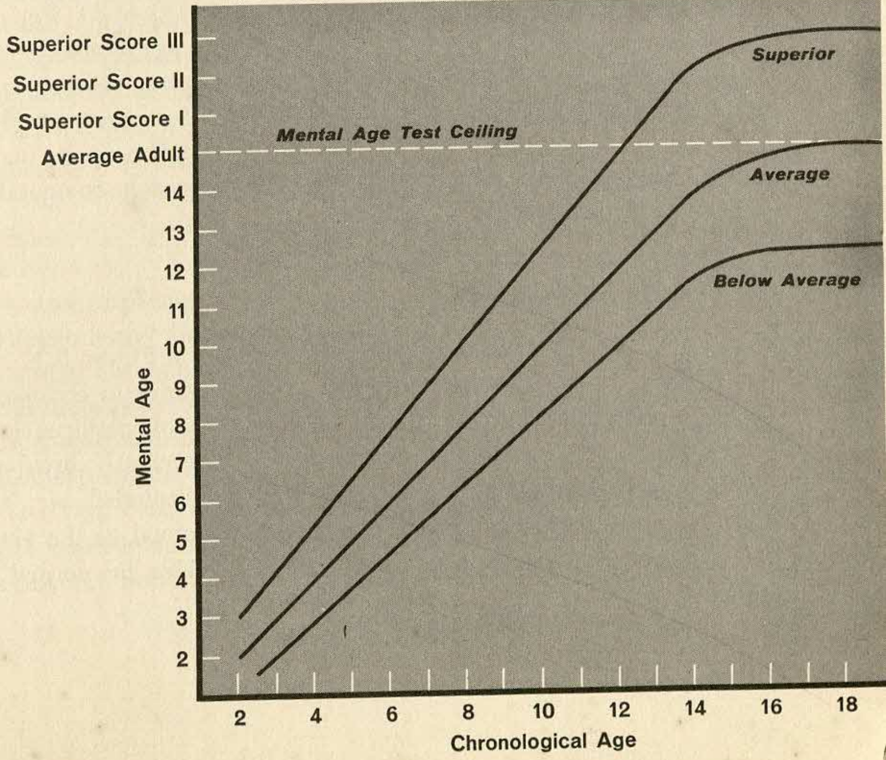
"I will say some numbers. When I am through repeat exactly what I said.

5 3 9 1 6 4

Now repeat them."

FIGURE 5.30. *Representative items from a test of intelligence for adults.*

FIGURE 5.31. *Relation between mental age and chronological age for three individuals.*



intelligence tests, psychologists have tried out a large number of such tasks on children of different age levels. The tasks are then grouped according to which ones the average child of each age can do. If, later, a child is tested and can perform the tasks which, say, the average 10-year-old can do, but none that the 11- or 12-year-old can do, he is said to have a "mental age" of ten years. His "mental age" would be 10 regardless of whether his actual chronological age was 8, 10, or 12. In other words, a child's mental age is the average calendar age of the children who pass the same number of items on an intelligence test that he does.

Mental age obviously tends to increase with chronological age, but the rate of increase varies with different individuals. Figure 5.31 shows the rate of development for three individuals. It will be seen that all of them at some stage reach a mental age of 10, but one arrives at this level at age 8, another at age 10, and the third at age 12. Some individuals never reach this mental age.

Thus, a given mental age may mean different things for different people. An MA of 10 for the 8-year-old indicates a rather superior individual; for the 10-year-old it indicates an average individual; for the 12-year-old it indicates an individual below average. The Intelligence Quotient, or I.Q., is a way of expressing this difference. It expresses the mental age *relative to* the chronological age. The I.Q. is obtained by the formula:

$$\text{I. Q.} = \frac{\text{MA}}{\text{CA}} \times 100$$

In our example, the 8-year-old with an MA of 10 has an I.Q. of 120; the 10-year-old, of 100; and the 12-year-old has an I.Q. of 80. Figure 5.31 also indicates that MA begins to level off at around age fifteen, beyond which there is little or no increase in intelligence-test scores. Hence, applying this I.Q. formula to adults is not really appropriate. Some tests simply use age fifteen as the CA regardless of age beyond fifteen. Some tests make other adjustments in order to render the I.Q. approximately comparable for different age groups beyond fifteen.

Distribution of I.Q.'s

The distribution of I.Q.'s is presented in Figure 5.32, which also indicates the several categorizations of intelligence in common use. The important thing to note is that the categories of intelligence are determined statistically. Intelligence-test scores are continuously distributed, but certain ranges are designated as near genius, feebleminded, etc. In the statistical sense, the very intelligent are just as abnormal as the very unintelligent. About 50 percent of the population falls within the normal range, which in

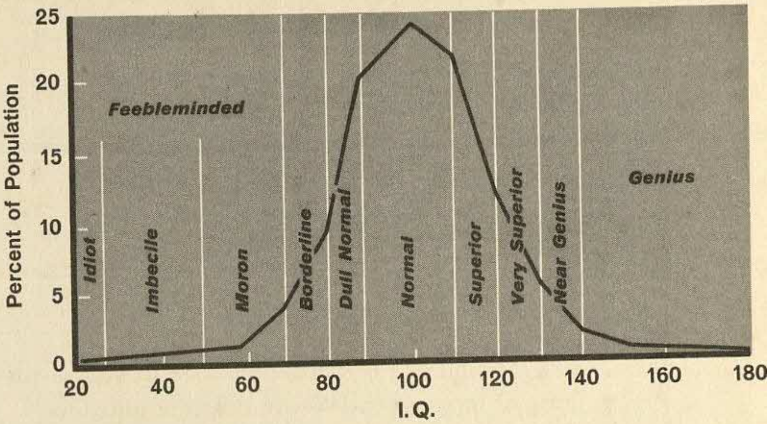


FIGURE 5.32. *The distribution of I.Q.'s for 2,904 children as measured by the Stanford Binet Test of Intelligence. Superimposed on this distribution are the ranges often designated as "feebleminded," "genius," etc. (After* Terman, L. M., and Merrill, M. A., Measuring intelligence. *Boston: Houghton Mifflin, 1937)*

I.Q. terms is from 90 to 110. Only 2.5 percent of the population have I.Q.'s of 70 or less, and similarly 2.5 percent have I.Q.'s of 130 or more.

Growth and Decline of Intelligence

We have indicated that scores on intelligence measures increase steadily to early adolescence and then begin to level off. By late adolescence, the measure of intelligence has reached a peak beyond which it does not ascend. Beyond the 20's there is a steady gradual decline in such test performance with age. Figure 5.33 shows a typical curve based on mental age equivalents for different age groups. By age seventy, the *average* man has an I.Q. of about 80. So far as intelligence is concerned, senility is a gradual process and not something that strikes one suddenly.

In considering the general decline in intelligence, it is important not to lose sight of the fact that intellectual accomplishment depends on other factors besides basic ability level. Specific practice, experience, and knowledge account for an increasing proportion of man's performance as he gets older. The professor is still able to teach his students in his specialized field even though some of his students surpass him in I.Q. However, as we have seen, his basic abilities place limits on the extent to which he can profit from his experience. A man with limited I.Q. will never become a wise man no matter how much experience he has.

Perhaps the major caution in interpreting the curve in Figure 5.33 is the fact that this curve is really a composite of many more specific abilities. Earlier in this chapter we have shown that different abilities increase and

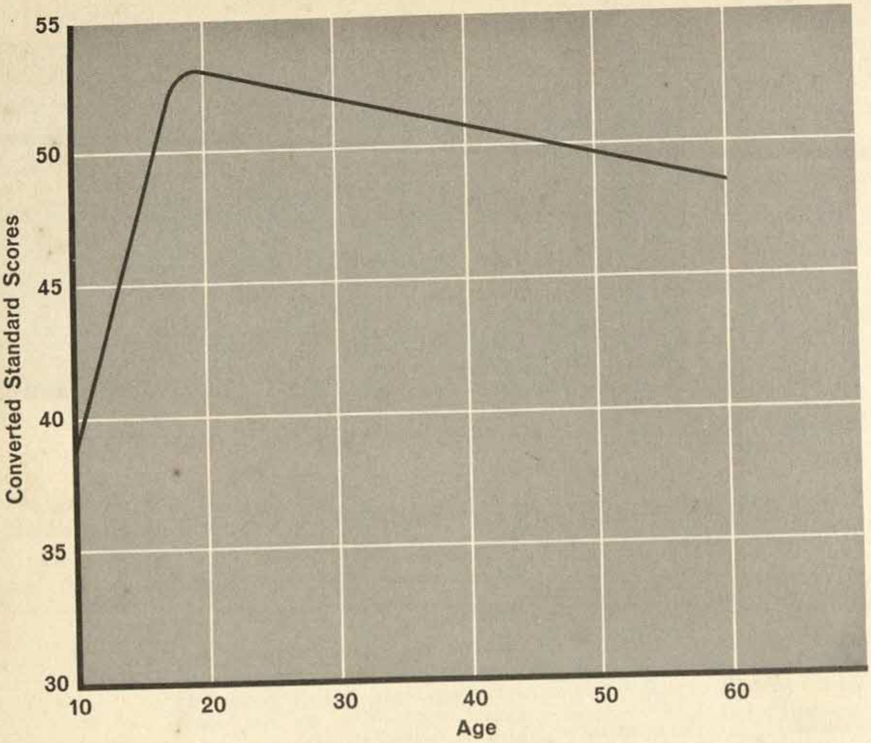


FIGURE 5.33. *Relation between scores on an intelligence test and age. (After Jones, H. E., and Conrad, H. S., The growth and decline of intelligence,* Genet. Psychol. Monog., *1933, 13, 223-298)*

decline at different rates. Figures 5.4 and 5.6 presented those curves for some separate component abilities. To the extent that an occupation requires certain discrimination, perceptual, or motor abilities, older people may suffer more when compared with young people. Verbal ability and certain conceptual abilities tend to be better maintained with age.

Cultural Differences

The question of cultural differences in intelligence test performances is indeed a complex one and can only be mentioned here. We have discussed this matter earlier in its relation to the separate abilities. The same conclusions apply to intelligence measures; namely, that early cultural and environmental factors play a role in the ability patterns developed. For example, Figure 5.34 presents a curve which compares the intelligence-test scores of Negro boys and girls of the same age who have lived in the North for various periods of time. It is clear that the longer the residence in the urban northern social environment, the higher the intelligence. Clearly, environmental factors have an important bearing on the development of the component verbal, thinking, and other abilities that make up "intelligence."

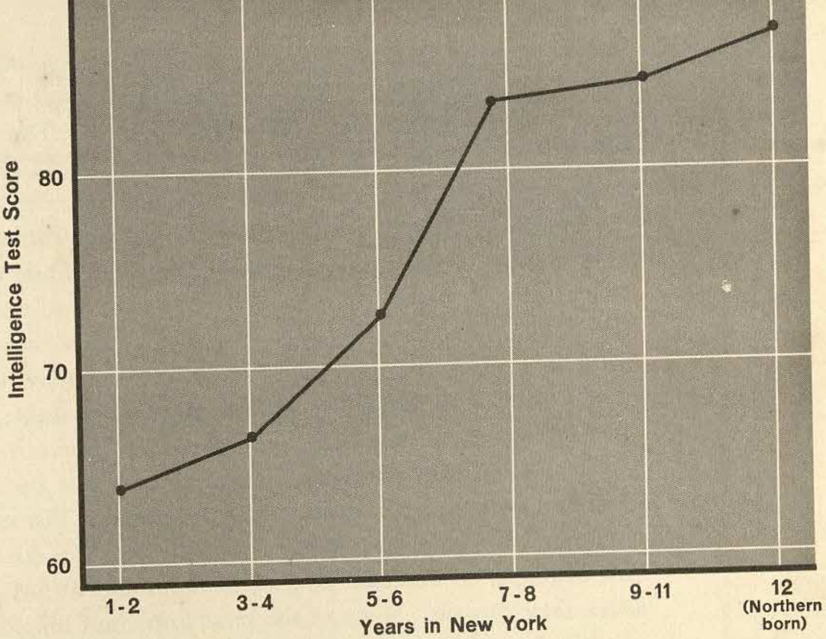


FIGURE 5.34. *Relation between scores on an intelligence test and years of residence in New York City for Negro boys. All the boys were twelve years old. (Data from Klineberg, O.,* Negro intelligence and selective migration. *New York: Columbia University Press, 1935)*

A Final Word about Intelligence

In general, intelligence tests are most suitable in evaluations of school-age children and for average or below average adults. In the former case, they have been invaluable in diagnosing "mental deficiency" before casual observation, medical and other techniques could have done so. For adults, information on intelligence is most useful as a preliminary screening or a general classification technique. As we shall see in Chapter 12, modern techniques of personnel selection tend to use combinations of measures of the different component abilities which are predictive of success in a variety of specific situations.

SUMMARY

People differ in their basic abilities. These differences affect the rate at which a variety of specific skills are learned as well as the final level of proficiency which can be attained in these skills.

A basic ability is a general trait of an individual which can contribute to the level of performance he attains on many specific tasks. The particular set of abilities a person develops depends on biological and physiological factors, but learning and environmental and cultural factors play a major role in influencing ability development. Through the process of *ability differentiation,* a great number of different abilities develop as a person progresses from infancy toward adulthood.

The basic abilities are identified through the *correlations* among actual performances of people on different tasks. Individual differences in ability are quantitative rather than qualitative; people tend to be distributed along a continuous scale in the amount of each ability they possess. Typically, this frequency distribution takes the form of the *normal curve.* Such distributions may be described by certain statistical concepts, the most important of which are measures of *central tendency* and measures of *variability.*

A considerable number of basic abilities has been distinguished and identified by means of correlational techniques. The names given to these abilities (like *spatial orientation, manual dexterity, concept fluency*) represent attempts to describe in general terms the variety of human performances they support. Some of the most important human abilities, the kinds of tasks to which they relate, and methods used to measure them, are described in the text of this chapter.

The term *intelligence* refers to a composite of certain basic abilities. The concepts of *mental age* and *I.Q.* are used to designate an individual's performance on certain measures of "intelligence." Categories such as "moron," "feebleminded," "genius," represent designated ranges of intelligence-test scores, and not sharp qualitative distinctions. Intelligence-test scores are distributed continuously, as are measures of the component abilities. Performance on measures of intelligence is partly a function of age and of cultural differences.

In later chapters we shall describe the practical significance of our knowledge of human abilities in evaluating the ability requirements of jobs, in developing personnel selection procedures, and in designing equipment for human use.

READING REFERENCES

Anastasi, A., *Differential psychology.* New York: Macmillan, 1958. A detailed account of research on individual and group differences in behavior.

Guilford, J. P., *Psychometric methods* (2nd Ed.). New York: McGraw-Hill, 1956. One chapter describes the mathematical techniques of factor analysis which psychologists apply to correlations in identifying human abilities.

Walker, H. M., and Lev, J., *Elementary statistical methods* (Rev. Ed.). New York: Holt, 1958. A basic text in statistics as used in the behavioral and social sciences.

Wechsler, D., *The measurement of adult intelligence* (3rd Ed.). Baltimore: Williams and Wilkins, 1944. A description of procedures for measuring intelligence with one of the standard adult tests.

6

LEARNING AND RETENTION

Starting with a foundation of general abilities, the human individual is able to modify his behavior to acquire a great variety of new skills. The present chapter describes the process of learning such skills, as well as the complementary process of their retention. The principles described here are applicable to the learning of simple habits, motor skills, identifications, and verbal sequences. More extensive accounts of all of these kinds of behavior will be encountered in later chapters.

As we have seen in Chapter 3, the performances of human beings which are commonly observed and measured are dependent upon the retention of previously learned habits, motor skills, verbal sequences, models, and concepts. The learning of these various specific skills, we found in Chapter 5, may be facilitated by the possession of some general abilities, which themselves in part owe their existence to a longer history of previous learning. We now turn directly to a consideration of the process of learning.

How do people acquire and retain the underlying skills which enable them to perform various human tasks? This question can be answered in terms of the conditions which must be established if human performances are to exhibit lasting changes. *Learning is the internal neural process assumed to occur whenever a change in performance, not due to growth or fatigue, exhibits itself* following the establishment of the conditions to be described here. The entire set of conditions responsible for learning is partly internal and partly external to the individual. Concerning the internal conditions, that is, the physiological and neural factors in learning, not much is known at present. The external conditions, however, have been investigated for many years, and can be specified quite dependably.

THE LEARNING OF SIMPLE HABITS

There are two reasons why it is peculiarly difficult to determine the conditions for the acquisition of simple habits in human beings. The first is that human adults, who are most readily available for such study, have already learned a great variety of such habits. It is not easy to devise an entirely new situation so that habit acquisition can be studied "starting from scratch." The second reason is that the human adult can most readily acquire new habits by using stored concepts; thus the process does not involve learning at all in the sense that we use the term here.

There are several ways around these difficulties, each of which has been tried with more or less success:

1. *Children* can be used as subjects in learning studies. It is fairly easy to put a child in a situation which is new to him. We can study the acquisition of simple habits such as reaching for the nursing bottle (when he is very young), or opening a latched door, or picking up a red-colored box to obtain a toy. When such learning is studied in children, though, two precautions are necessary for valid results. First, the child must not be too young, else one cannot be certain that the nervous system has matured sufficiently for the learning to be truly representative (and not just the reaction of an immature nervous system). Second, the child must not be too old, else he will have acquired many of the same concepts that adults have, and so be able to use them in acquiring new behavior patterns. Sometimes it is difficult to choose a child of the right age for study, in attempting to avoid these two horns of a dilemma.

2. *Reflex responses* of adults can be attached to new signals and thus be acquired as new habits. For example, the reflex eyelid-blink to a puff of air on the cornea of the eye can be "conditioned" to other signals such as the sound of a buzzer. Or the reflex response known as GSR (the galvanic skin reflex, a change in the electrical conductivity of the skin in response to a mild electric shock) can be attached by a learning process to a new signal such as a tone or light. Such reflex responses are particularly useful in this respect because they cannot ordinarily be controlled by the use of concepts. (The "involuntary blink" of our first example is not the same as the "voluntary blink"; the latter is, as its name suggests, controllable by the use of concepts.) Therefore it is possible to study the acquisition of a simple habit such as Signal (tone)–Response (GSR) and to demonstrate at the same time that the individual could not have acquired this habit by using

the rule "Lower the skin's electrical resistance when you hear the tone." Habits which represent the attachment of new signals to reflex responses are called *conditioned reflexes.* These will be discussed at greater length in a later section.

3. *Animals* have been extensively used in studies of simple-habit learning. They have many advantages for this purpose. Their motivation can be controlled readily; for example, by restricting their food intake to measured amounts. From many lines of evidence, it can be assumed that an animal like a white rat or pigeon is unable to form or react to concepts; he cannot "figure out" what the experimenter is doing. However, it appears that this assumption is at least risky in dealing with monkeys, and unlikely for the higher apes. Finally, it may be assumed that the basic structure and function of an animal's nervous system (though not its "higher loop" organization, of course) is quite similar to a human being's. Consequently, we may suppose that simple habits are acquired in much the same way by an animal as by a man.

An Example of Simple-Habit Learning

In order for us to describe the conditions which govern the acquisition of simple habits, it will be useful to have in mind an example. We shall use a case of animal learning.

A white rat is to learn the habit of going out of a "starting box" to a "food box" along a narrow elevated runway, as shown in Figure 6.1. As is implied by the name, the food box contains a bit of food which the animal eats each time he has traversed the runway. The animal has had previous

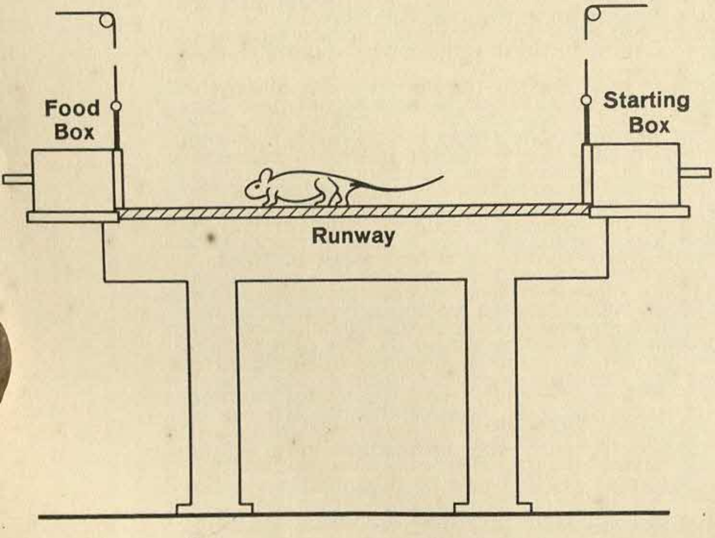


FIGURE 6.1. *A elevated runway used to study the learning of simple habits in the white rat. When the door of the starting box is raised, the animal runs from the starting box along the runway to the goal box, where he receives a bit of food. (From Graham, C. H., and Gagné, R. M., The acquisition, extinction, and spontaneous recovery of a conditioned operant response,* J. exp. Psychol., 1940, *26, 251-280)*

experience in running along narrow runways like this, and he has also eaten food in boxes similar to the food box; so that it is not these activities the animal is being asked to learn in this situation. Instead, he is simply required to learn the habit of running out of the box (and down the runway), as opposed to staying in the box, when a signal is given. The signal in this study was the opening of a door in front of the starting box, which let in some additional light.

In this experiment, learning of the simple habit was measured in a series of "trials," with a constant interval of 75 seconds between them. Each trial began with the signal of opening the starting-box door, and ended when the rat reached the food box and ate the bit of food placed there. What was measured was the time taken by the rat to leave the starting box after the door was opened, that is, to cross a line four inches in front of the starting box on his way down the runway. In other words, the progress of learning in this study was reflected in increasingly rapid "running-out-of-the-box" responses to the signal of opening the door.

When a hungry rat is first placed in the starting box of this apparatus, and the door opened, his behavior is active and varied. He sniffs the air, the sides, top, and back of the box; he scratches the box; he licks his fur; he peers around in all directions. After a greater or lesser time devoted to these activities, he runs out of the box and down the runway, finds the bit of food, and eats it. When he is again put in the starting position, and the door opened to start the second trial, it is easy to see certain changes in his behavior. Although he again engages in varied activities such as scratching and sniffing, these are now reduced in number and duration. Furthermore, he exhibits a greater tendency to orient himself toward the front of the box, toward the runway. On the second trial, in a fraction of the time it took him on trial 1, he runs out of the box again and down the runway. Successive trials bring about further reductions in these random or "staying-in-the-starting-box" activities, and further increases in the speed with which the animal leaves the box on his way to food.

The learning of this simple habit by the white rat is shown as an increase in speed and dependability of the response of running out of the starting box to the signal provided by opening the door. Another way to say this is that the probability of the response of running out of the box (within a given time interval) has increased from a very low value to a very high value. Furthermore, this change in the animal's behavior is a relatively permanent one. If we return this same hungry rat to the starting box tomorrow, or next week, or even next month, the response of running out of the box will still be highly probable, and will appear within a short period of time, relative to the behavior of other rats who have not learned this simple habit.

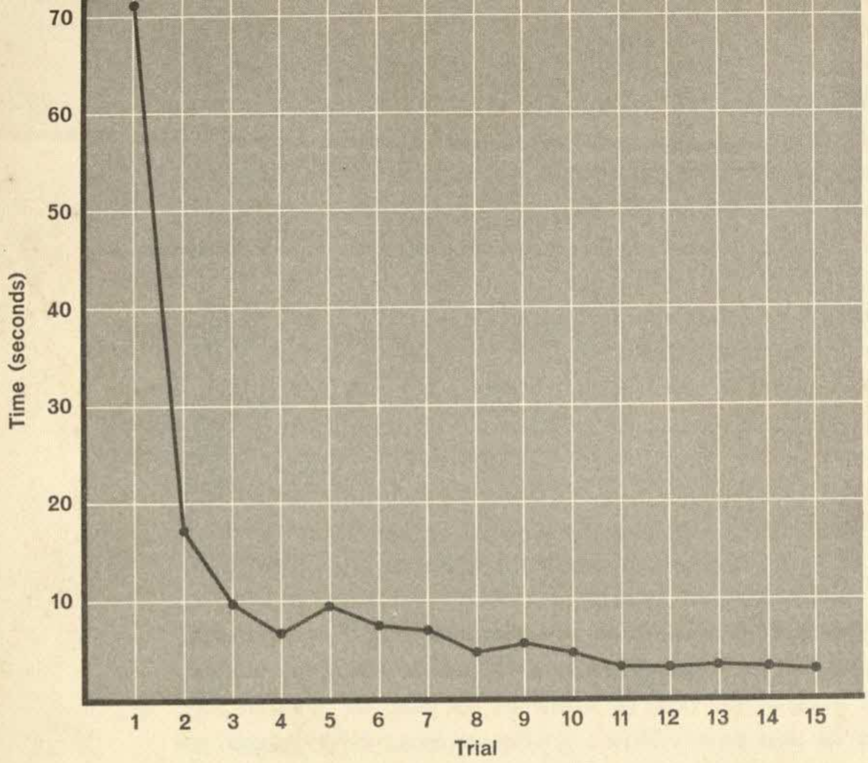


FIGURE 6.2. *Learning of a simple runway habit by white rats. The geometric mean of the time taken to leave the starting box is plotted for 21 rats in 15 practice trials. (Data from Graham, C. H., and Gagné, R. M., The acquisition, extinction, and spontaneous recovery of a conditioned operant response, J. exp. Psychol., 1940, 26, 251-280)*

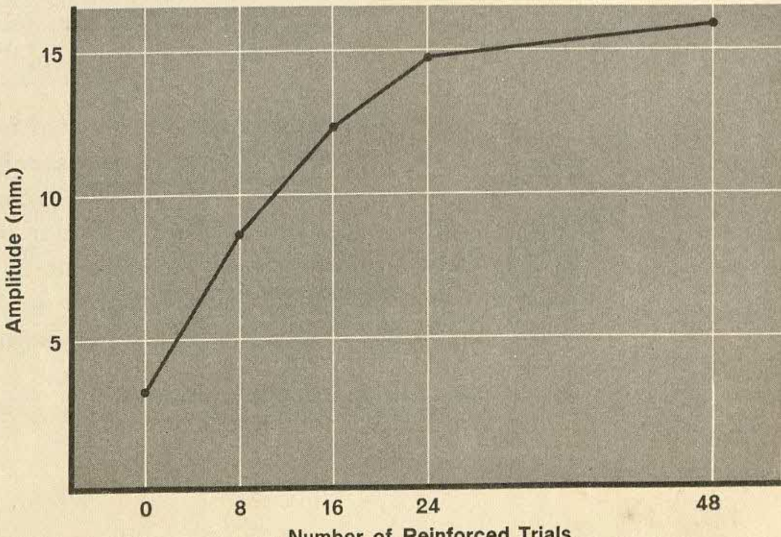
Figure 6.2 shows the change in the time taken to leave the starting box in fifteen learning trials for a group of twenty-one white rats who acquired this simple habit in the manner just described. Average (geometric mean) values of this time are plotted in the graph. A learning curve for any single animal, of course, would show much greater variation than this from trial to trial. But the negatively accelerated form, indicating a continued decrease in time of response and approaching some minimal value, may be taken as typical of the behavior of all animals in this situation. Furthermore, it is similar in general form to that obtained on other simple habits in animals.

The Conditioned Reflex

As we mentioned earlier, a special instance of simple-habit learning is called the *conditioned reflex*. This was discovered and described by the Russian physiologist Pavlov, who worked primarily with dogs as experimental animals.[1] When a dish of food is placed before a hungry dog, his salivary glands begin to secrete saliva. This original signal-response sequence Pavlov called the *unconditioned reflex.* When the presentation of food is accompanied in a series of trials by the sound of a bell, the bell alone acquires the property of eliciting the response of salivation. The bell was given the name the *conditioned stimulus,* and the newly-acquired habit, S(bell)—R(salivation), was termed a conditioned reflex. It was possible to measure the strength of this new habit, following varying numbers of trials in which the bell was followed by the presentation of food, by the increase in the amount of saliva secreted to the stimulus of the bell alone.

Conditioned reflexes of various kinds have been established experimentally in human beings. The knee-jerk, for example, can be conditioned. However, two of the most convenient reflexes which have been conditioned in human beings are the *eyelid, or blink, reflex,* and the increase of electrical resistance of the skin, the *galvanic skin reflex* or GSR. The learning of habits of this sort is subject to essentially the same conditions, and reveals the same general course of acquisition, as does the learning of simple habits in children or animals. Figure 6.3, for example, shows a learning curve obtained in the human acquisition of a GSR response to a tone. Originally, a mild electric shock produced the GSR response of reduced electrical resistance of the skin; the tone produced no such reaction. The habit of response to the tone was established in successive trials of practice, in which the tone and the shock were delivered together. On the particular trials shown, a "test" with the tone by itself gave the strength of responses shown in the graph.

FIGURE 6.3. *The acquisition of a conditioned galvanic skin reflex (GSR) in human beings. Strength of the learned response is shown as average amplitude of deflection of a galvanometer, indicating the amount of reduction in skin resistance. (After Hovland, C. I., The generalization of conditioned responses: IV. The effects of varying amounts of reinforcement upon the degree of generalization of conditioned responses,* J. exp. Psychol., *1937, 21, 261-276)*



CONDITIONS OF SIMPLE-HABIT LEARNING

Let us now make a systematic review of the conditions of simple-habit learning, which we have mentioned in connection with the previous example of the runway habit in the white rat.

Motivation

First of all, we had a hungry animal; that is, he was motivated to search for, find, and eat food. If the rat were not motivated, we could not have counted upon him to exhibit the varied activity, which included the response of running out of the box, that we wanted to connect with the signal of door-opening. Instead, he might have curled up and gone to sleep. In any case, he would have been relatively inactive, and the probability of his running out of the box on the first trial would have been extremely low. For learning to occur at all, we must have a motivated animal.

Motivation can take many forms. An animal like a rat may be motivated by hunger, sex, avoidance of pain, or even a drive to explore his surroundings. Dependable sources of motivation in both animals and men are the fundamental drives we have discussed in Chapter 4. A reflex, which as we have seen may be employed as a basis for simple-habit learning, represents another dependable source of motivation, a kind of "localized drive." In human beings, the variety of motivation is tremendous, since it includes not only the fundamental drives but all sorts of acquired goals and purposes, such as we have previously described.

Reinforcement

Another very important condition of learning illustrated by our example is that the activity set in motion by the hunger motivation, and which we desired to connect with the signal of door-opening, was followed by eating of food. This condition of following a signal-response sequence more or less immediately with a reward is called *reinforcement*. The habit which begins to be acquired because of this sequence of events is said to be *reinforced*.

The condition of reinforcement is essential for simple-habit learning. As we shall see later, unless the rat in our example actually consumes the food at the end of each trial, learning does not occur, regardless of how frequently we may get him to leave the starting box and traverse the runway. In human learning, too, reinforcement is just as necessary, even though it may take the form of a "sense of accomplishment" for having learned something, rather than being a physical reward.

What kind of internal events follow the application of the condition of reinforcement? Why does reinforcement "stamp in" the habit? There are quite a number of theories about this effect, none of which can be considered well established at the present time. One type of theory holds that some physiological effect on synaptic conduction (possibly acting through the blood) results from drive-reduction, and thus facilitates the establishment of new habitual connections in the nervous system. A second type of theory holds that the animal tends always to repeat the last behavior he exhibited previously when in the same situation, provided he is not distracted by new stimuli. According to this conception, activity such as running down the runway and eating food at the end of it serves to get the animal out of the "starting-box situation." Thus the presentation and eating of food serves only to preserve and perpetuate the behavior which occurred previously, namely, running out of the starting box, and prevents the learning of alternative conflicting responses. Furthermore, the excitement produced by the drive gets "channeled" into the running response, which therefore increases in strength. According to a third view, what the animal acquires is not simply a neural connection between stimulus and response, but rather a model of the entire situation including the signal, the door, the runway, and the food. This conception would make habits not dependent upon a simple-habit memory, as we have assumed, but would instead maintain that learning a habit results in modification of the scale and model memory. Reinforcement is assigned a more subordinate role by this theory, since it becomes merely the terminal act in a sequence, rather than a direct cause of the "stamping in" of habits.

We cannot attempt here to review the various implications of these theories, nor the different lines of evidence for and against each. The matter of what internal events are correlated with learning is an intriguing scientific question which is currently being studied by many investigators. The interested student will find a number of references to introduce him to the problem (see Reading References). For present purposes, it is sufficient to state that regardless of how it operates, reinforcement is an important condition of learning. The satisfaction of some drive or motive must occur shortly following the habitual activity in order for learning to take place.

Repetition or Practice

The learning of a habit requires the repetition of the signal-response-reinforcement sequence in a number of practice trials. As we have seen in our example, the greatest change in behavior occurs following the first trial, with progressively smaller changes following in successive practice trials. Sometimes, the habit is so "easy" to learn that there may be no measurable increase in its strength following the second trial. Presumably, the stimulus-situation which includes the signal may be so readily distinguishable from the same situation without the signal that the habit acquires its full strength from a single trial.

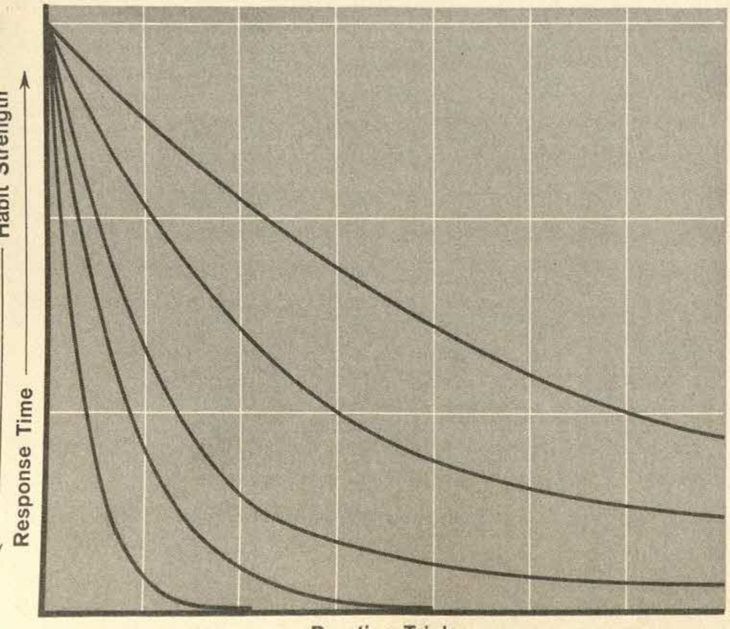
Thus there is a whole family of learning curves, different ones of which will show the learning of different habits, as indicated in Figure 6.4. The relationship between number of trials of (reinforced) practice and habit strength is one which typically shows negative acceleration. That is, the increments of habit strength are great at first and grow progressively smaller as practice is continued. The slope of the curve, however, depends upon the difficulty of the task which has been set for learning.

As indicated in Figure 6.4, the simplest habits are often learned to perfection in a single practice trial; difficult ones may yield gradual slopes of learning curves. In the figure, as in many studies of learning, habit strength is assumed to be measured inversely by response time. The general rule is: *The strength of a simple habit increases in a negatively accelerated fashion with the number of reinforced practice trials.*

Emotional Interference

A strong generalized response typical of emotion may interfere with the acquisition of a simple habit. A white rat in a starting-box situation,

FIGURE 6.4. *A family of theoretical curves of learning. The increasing strength of the habit is assumed to be the inverse of the response time, as shown on the vertical axis. A very easy task may result in an extremely steep slope for the learning curve; a very difficult task in a very gentle slope. Tasks of intermediate difficulty fall in between.*



for example, may fail to show learning for several trials when he is subjected to a loud noise, an electric shock, or to other stimulation which may be assumed to arouse an emotional response in him.[2] The importance of this fact is to be found particularly in the effects of punishment on learning, which will be discussed in a later section. For now, it may be noted that the learning of simple habits follows its typical course only when the situation is free from strong distracting stimuli which produce emotional responses.

Summary of Learning Conditions

The four important conditions under which the learning of simple habits takes place are: (1) a motivated individual; (2) reinforcement shortly following the signal-response sequence to be acquired; (3) one or more practice trials providing repetition of the signal-response-reinforcement pattern; and (4) freedom from distracting emotional stimulation. The strength of the acquired habit increases in a negatively accelerated manner with increased practice. The slope of the curve, however, depends upon the difficulty of the task which defines the habit to be learned.

EXTINCTION

Once learned, a habit may be deliberately erased, as a result of a set of conditions called *experimental extinction* or simply *extinction.* A habit suffers extinction when the reinforcement is removed. In other words, continued repetition *without reinforcement* leads to a progressive decrease in habit strength until the habit disappears altogether.

Figure 6.5 shows the extinction of the runway habit in the same group of rats which originally learned it. As the figure indicates, during five practice trials each of which terminated *without* food, the response of leaving the starting box slowed up progressively. After five such trials it was slower than the response on Trial 2 of the original learning. Presumably, additional unreinforced trials would have brought the habit to complete extinction.

Internal Events in Extinction

Why do we say extinction is an active process? In the first place, it is fairly *rapid.* A habit can be brought to a fairly low degree of strength in a relatively short period of time filled with unreinforced trials. The same amount of decrease in habit strength would take considerably greater time if we merely allowed time to pass, and did not require active exercise of the response. The latter set of events occurs in *forgetting* (to be described more fully later).

Secondly, there is the phenomenon called *spontaneous recovery*. If we extinguish a learned response to a given level and then allow a period of time to go by before presenting the signal, the response will momentarily recover some amount of its previous strength. Extinction then proceeds in the usual way from this new point with additional unreinforced trials.

A third phenomenon is known as *external inhibition*. A distracting stimulus applied just before the signal during an extinction series will also cause the learned response to increase in strength on the following trial. This effect is transitory, and the response soon drops again below the level it had before the distraction was introduced.

All of these facts have led to the conclusion that extinction is not a passive decay process, but rather results from an active neural process which Pavlov, who discovered it, called *inhibition*. A distraction or a delay may evidently interrupt this active process of inhibition temporarily, thus revealing an underlying amount of habit strength which was not previously apparent from the measured performance. Of course, continuation of the conditions of extinction will ultimately reduce the habit strength to zero.

Extinction has a practical importance when one wants to get rid of undesired habits. For example, some people have found the principles of extinction to be of value when they have decided to quit smoking. If one follows the rule that the way to stop smoking cigarettes is to "just quit," he

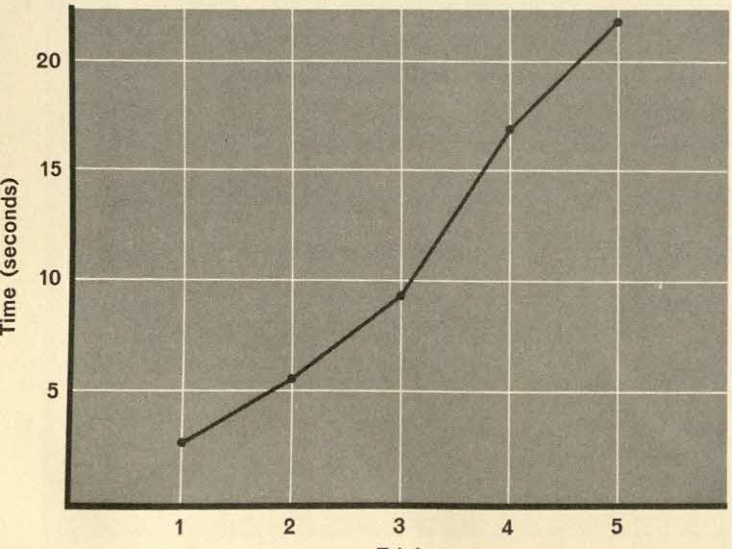


FIGURE 6.5. *Extinction of a simple habit. This is the runway habit in the 21 rats which learned as shown in Figure 6.2. Geometric means of time taken to leave the starting box are shown during five unreinforced trials. (Data from Graham, C. H., and Gagné, R. M., The acquisition, extinction, and spontaneous recovery of a conditioned operant response,* J. exp. Psychol., *1940, 26, 251-280)*

is depending on the disappearance of many smoking habits through forgetting alone. In such circumstances, he may find himself craving a smoke on many occasions over a period of weeks or months. Using extinction, however, the individual may place in his mouth a false cigarette or pipe-stem. When the signal provided by such stimulation is followed by the response of "puffing," no satisfying inhalation of smoke occurs. This practice, then, is an example of repetition of a set of the crucial habits in smoking without reinforcement. Although there is no firm evidence on this point, there are many reports of the effectiveness of such a method.

We have seen that the extinction of a habit takes place under conditions of repetition of the signal-response sequence without reinforcement. The phenomena of spontaneous recovery and external inhibition show that extinction depends upon an internal process of *inhibition.* Together with the fact that extinction is relatively rapid, this serves to distinguish extinction from forgetting, and to show that it may be conceived as an active *erasing* process for learned activities.

THE LEARNING OF MOTOR SKILLS

As we saw in Chapter 3, motor skills may be looked upon as sequences of simple habits. The signal for each response in the sequence after the first comes from some effect of the previous response, either internally through the kinesthetic sense, or through some other sense from the external environment. What we have to consider, then, is a chain of signal (S) and response (R) events something like this:

$$S_1\text{–}R_1 \longrightarrow S_2\text{–}R_2 \longrightarrow S_3\text{–}R_3 \longrightarrow S_4\text{–}R_4,$$

in which S_2 is produced either in a direct internal way or in a roundabout external way by the occurrence of R_1; S_3 is produced by the occurrence of R_2; and so forth.

As we also noted in Chapter 3, the individual responses which make up the total act may be readily identifiable as *discrete* units, or they may form themselves into a *continuous* activity in which such units can only be identified in an arbitrary fashion. If we instruct an individual to "Draw a square without lifting your pencil from the paper," the four individual lines may be considered as unitary responses, each of which is determined by the visual stimulus provided by the sight of the previous line or lines. On the other hand, if we say, "Draw a circle," the length of curved line which constitutes a unit of response may be impossible to determine in any given instance. As a consequence of this fact, the learning of skills has generally been studied in terms of the total skill, and only a limited amount of investigation has been made of the much more difficult question of how the unitary components of skills come to get chained together.

The Conditions of Motor-Skill Learning

Because the learning of a motor skill, according to our analysis, must involve the acquisition of a *sequence* of new signal-response connections, it is not surprising to find that many of the fundamental conditions of simple-habit learning apply to learning motor skills too, even when we are talking of total skills rather than the units which make up the total. Thus we find that motor-skill learning as well as simple-habit learning is dependent upon the existence of *motivation*, of *reinforcement*, of *practice*, and of *freedom from emotional interference*. In practical situations, most of these conditions are fairly obvious; only when they are absent does their importance become apparent.

In learning to toss two balls with one hand, an elementary skill of juggling, the individual must of course be motivated to learn; otherwise he may "go through the motions" without learning anything. Furthermore, if we increase his motivation, by getting him to compete with another learner, or by providing some monetary incentive, the resulting learning will be speeded up. The reinforcement in this situation is provided by the achievement of catching the balls; we say the individual has "immediate knowledge of results," since the success of each catching response is immediately apparent to the learner. Note that there are skills in which the "knowledge of results" may be considerably delayed, or even given only very occasionally, as in firing an aerial gun at a distant aircraft. The evidence is that skills are very difficult to acquire under such circumstances. Emotional responses may be shown to interfere with the learning of a skill; if we frighten the individual while he is learning the ball-tossing skill, his learning will be slowed down. Finally, the importance of repeated practice trials is very evident. We can describe ball-tossing to the individual in great detail, but increase in skill can come only through practice.

The Course of Motor-Skill Learning

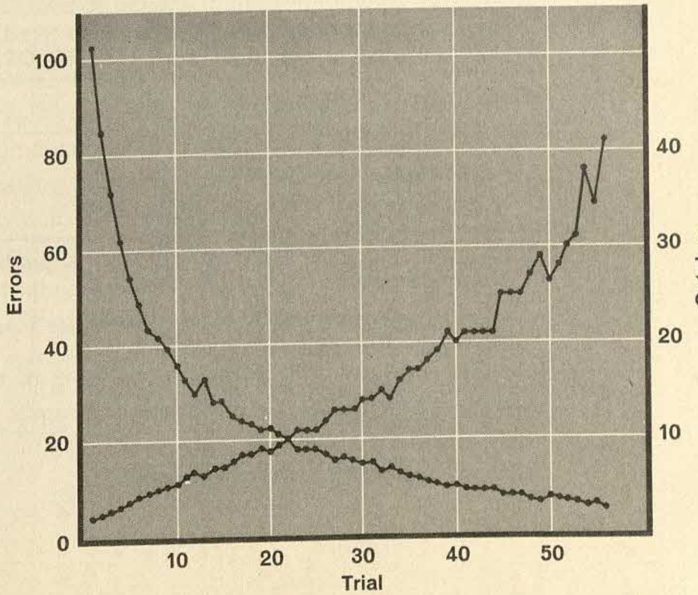
The effect of application of these learning conditions shows itself as an increasingly successful performance of the skill in question. The improvement in performance may be measured in a number of ways. Increasing *accuracy* may be measured, as in shooting a rifle at a bulls-eye, in which the score is a weighted expression of the linear distance of the bullet holes from the target's center. The same performance could also be measured, if we chose, by the *number of errors* per given number of shots. This might be done by defining all holes within a certain distance from the center as being "correct," and all others as "incorrect" or as "errors." Another measure which this suggests is simply *number of correct responses,* again defined in the manner indicated. Such a measure may readily be applied to ball-tossing, where the number of catches and the number of errors within a given number of practice trials are inverse to each other. There are also situations (as in typing) where it is convenient to measure *number of correct responses within a given time,* rather than to attempt to measure the correctness of response on each "trial."

Each of these measures of learning gives a somewhat different learning curve, as might be expected. Correct responses, and response accuracy, would be expected to increase as learning proceeds, whereas number of errors will decrease. An example of the relation between learning measured as number of correct responses and measured as errors is shown in Figure 6.6 for the skill of ball-tossing. Since this is only the first part of learning, the negatively accelerated part of the curve for "number of catches" has not yet appeared in these results. It is evident that any learning curve will ultimately "level off" when an upper limit of performance is reached.

LEARNING VERBAL SEQUENCES

Just as simple habits involving motor responses may be chained together by a process of learning, so also may single verbal responses. This is

FIGURE 6.6. *Learning curves for the skill of ball-tossing. One curve is based on number of errors made in successive trials, each trial consisting of 200 attempted catches. The other curve indicates "correct responses," measured as number of successive catches before the ball was dropped. (Data from Peterson, J., Experiments in ball tossing: The significance of learning curves, J. exp. Psychol., 1917, 2, 178-224)*



what happens in "memorization" of a prose passage, a poem, an automobile registration number, or the value of π to twenty places. In the laboratory, what has been studied most often is the learning of serial lists of nonsense syllables. (A nonsense syllable is a combination of letters which does not spell or sound like a meaningful word, for example, KOJ.)

Meaningless syllables have been used to study verbal-sequence learning in order to insure a clear differentiation between simple chaining and the use of concepts. To learn the sequence "The boy and the man ate two cuts of pie" is obviously a very different kind of activity than to learn the equally long sequence "Kej sib paf yop mec juf nas gex tif nuk." Presumably, we recall the first, after one reading, because we have stored the "thought"; in other words, we have been able to utilize existing concepts about men and boys and pie, as well as concepts of English grammar, to arouse this particular sequence of verbal responses when asked to do so. In the case of the second sequence, there are no corresponding concepts, and we require a number of practice trials in order to learn it completely. Special care must always be taken, when studying verbal-sequence learning, to eliminate the influence of concepts—which is by no means easy to do. Obviously, a sequence like "BAL CEN TEX LUV JON" has a good deal of meaning, and can be recalled by utilizing a concept-sequence such as "The ball is in the center of Texas with love from John," however ridiculous that may be. Meaningful verbal sequences such as stanzas of poetry, therefore, depend for their learning only partly upon the acquisition of connections between individual verbal responses; to a large extent they are recalled by using already existing concepts. A representative set of results which shows the importance of this factor of meaningfulness is given in Table 6.1. The number of trials required to learn meaningless material is always much greater than is the case for meaningful words or sequences.

TABLE 6.1
NUMBER OF TRIALS REQUIRED TO LEARN MEANINGFUL AND MEANINGLESS SEQUENCES OF VERBAL MATERIAL

MATERIAL	AVERAGE TRIALS TO LEARN
15 nonsense syllables	20.4
15 unrelated words	8.1
15 related words	3.5

(From Guilford, J. P., *Laboratory studies in psychology.* New York: Holt, 1934.)

Some Important Conditions in Learning Verbal Sequences

The rapidity with which the learning of verbal sequences takes place, and the form of the learning curve obtained, vary greatly with the *length*

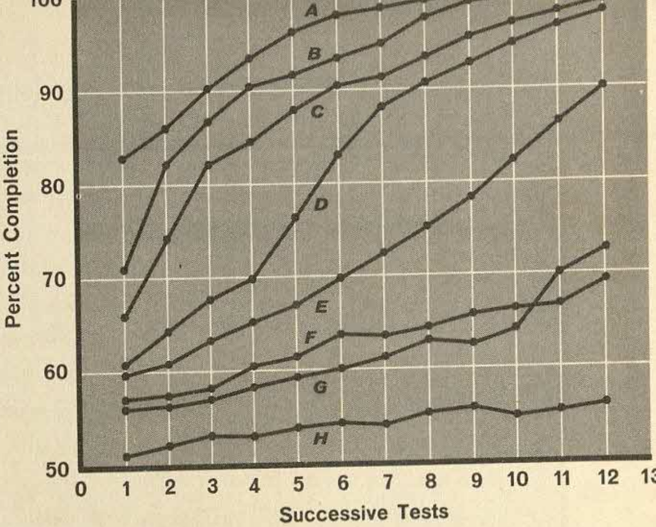


FIGURE 6.7. *Learning curves for sequences of nonsense syllables, varying in difficulty and length. A, 5 easy items; B, 15 easy items; C, 50 easy items; D, 100 easy items; E, 5 difficult items; F, 15 difficult items; G, 50 difficult items; H, 100 difficult items. (After Krueger, W. C. F., Rate of progress as related to difficulty of assignment, J. educ. Psychol., 1946, 37, 247-249)*

of the sequence, as well as with its *difficulty* which is dependent on such factors as meaningfulness and the tendency of various verbal habits to interfere with one another. Figure 6.7 indicates the variety of learning curves which may be obtained, depending on variation in these conditions.

As in the case of motor skills, it is not possible to specify beforehand the nature of quantitative changes in performance which will result from reinforced practice, until the factors of meaningfulness and interference can be more precisely measured than is possible today. All that we can safely conclude is that increased practice with reinforcement brings about a steady increase of performance excellence in the acquisition of verbal sequences, until mastery is reached.

Interference in Sequence Learning

The tendency of individual S-R habits to interfere with each other during the course of learning verbal sequences is a very important characteristic. When one is faced with the task of acquiring a sequence of nonsense syllables 1 through 12, for example, the signal for response No. 1 becomes attached through practice also to response No. 2 and to response No. 3, and so on to a decreasing extent throughout the list. Likewise, the signal for response No. 2 (which, in a sequence, is the sight and sound of syllable No. 1), becomes attached to response No. 3 and response No. 4, and so on. The existence of these "remote associations" has been shown many times in investigations of verbal-sequence learning.

It is evident that these remote associations constitute interfering tendencies in the learning of a sequence. Syllable 1, which should signal Syllable 2, has a strong enough association with Syllable 3 that sometimes the

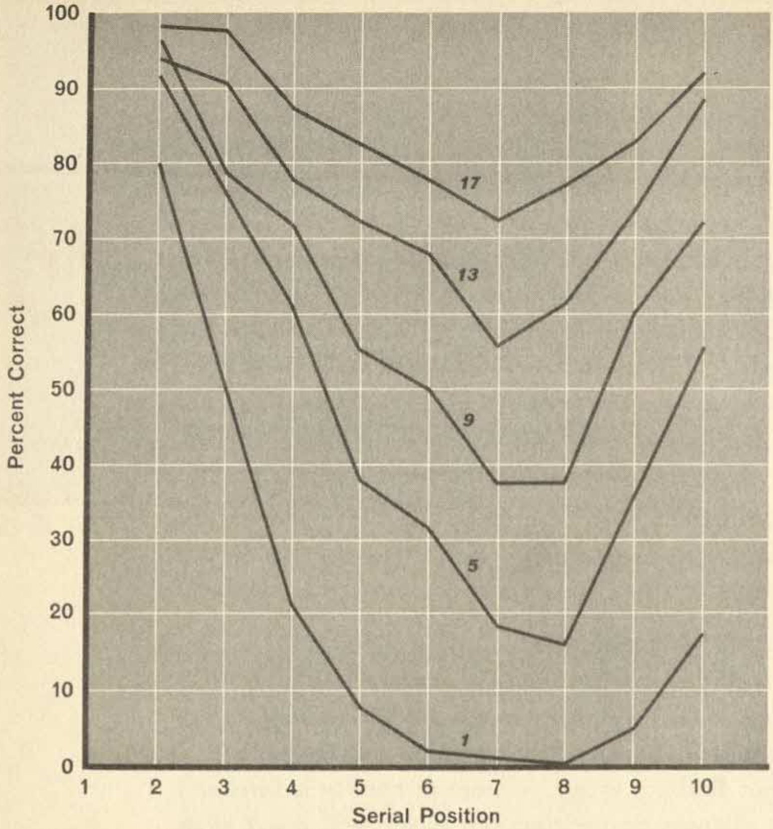


FIGURE 6.8. *The tendency of the items on the two ends of a sequence to be mastered before the middle items is exhibited in this graph, which is averaged from the learning of eight different sequences of 10 three-place numbers by 11 different individuals. Percentage of correct anticipations (of the next item) is shown for each of the ten items in the sequence, on practice trials 1, 5, 9, 13, and 17. The items were exposed one at a time at the rate of one three-place number every 2 seconds. As practice progresess, mastery of the lists seems to proceed from both ends inward to the center. (Data from Robinson, E. S., and Brown, M. A., Effect of serial position on memorization, Amer. J. Psychol., 1926, 37, 538-552)*

latter is given as the response rather than the former. This is shown by the fact that a high percentage of the errors made on initial practice trials are those in which the learner uses syllables which are members of the list, but which are given in the wrong order.

For some reason not yet explained in a completely satisfactory way, errors resulting from interference tend to pile up in the middle of the sequence being learned. Figure 6.8 shows how this tendency exhibited itself on practice trials 1, 5, 9, 13, and 17 of the learning of sequences of 10 three-place numbers. The percentage of correct anticipations of the items in the sequence (which is, of course, the inverse of the number of errors) was greatest at the two ends. As practice continued, the percentage of errors toward the center of the list (actually, around item 7 in a sequence of 10) underwent a progressive reduction.

Since the difficulty of learning verbal sequences is to a large extent attributable to interference, sequences increase in difficulty as they increase in length, mostly because of this factor. Similarly, sequences are more difficult to learn when the items are more similar to each other, because this increases the tendency for one response to be substituted for another, thereby producing interference. If one is searching for sequences that are easy to learn, he chooses those which are short and in which the items are least similar to each other.

IDENTIFICATION LEARNING

As we have seen in Chapter 3, another human behavioral function that is acquired by a learning process is the identification of stimuli in terms of a stored model or scale. The learning of models and scales, like the learning of skills, involves the use of a number of previously acquired simple habits. Rather than being chained together in a sequence by learning, these habits function to make possible separate identifications of each point on a scale (or of a set of models), so that in most instances the individual responses may appear in any of several orders.

The size and precision of the scale determine how many points must be separately remembered. Consequently these factors are of primary importance in determining how rapidly the scale may be learned. If we simply ask an individual to identify a right turn from a left turn at a crossroads, we may find he has already acquired such a scale. On the other hand, if we put him at a road junction which has six branches 30° apart, it may take some practice before he can identify each of these correctly. Similarly, the models which make up a set to be identified may be more or less difficult to learn. Some examples of model sets which vary in precision and in number of identification habits required, are given in Figure 6.9.

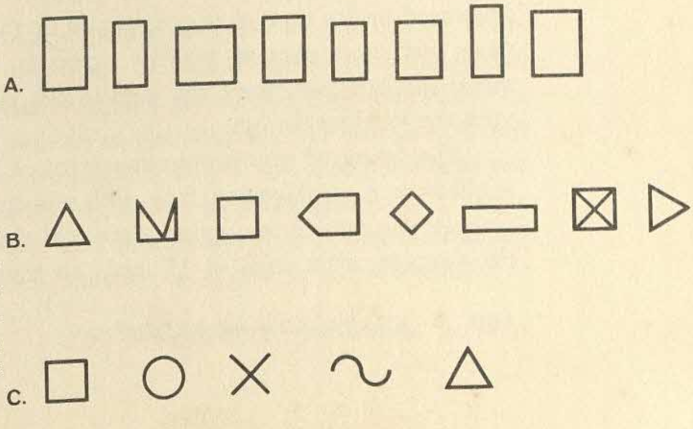


FIGURE 6.9. *Examples of model sets which vary in size and precision. A is a model set of greater precision than B. Learning to identify the figures of A by means of separate identification responses would require considerably greater practice than learning to identify the figures in B. Model set C is of approximately the same precision as B, but smaller, requiring fewer identification responses. C would therefore require a lesser amount of practice to learn than would B.*

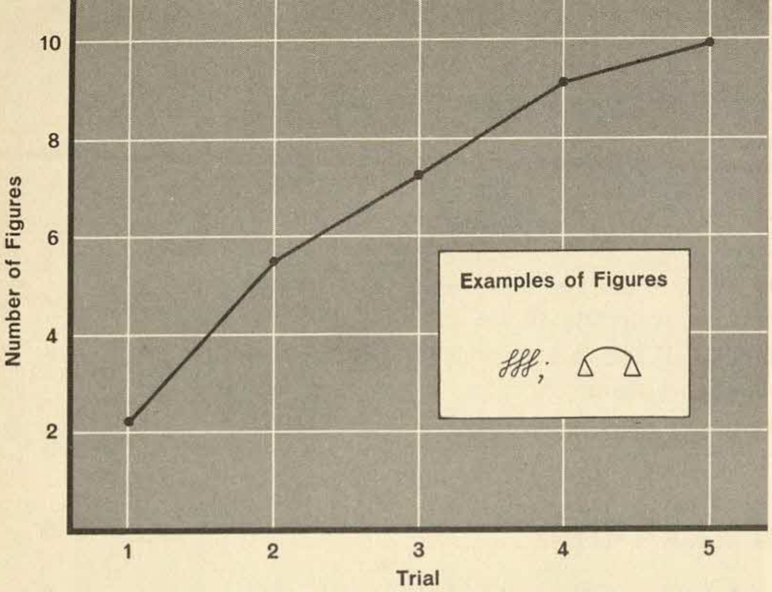


FIGURE 6.10. *The identification learning of 13 nonsense figures, of which two examples are shown. Average correct responses are plotted for five practice trials. (Data from Gibson, E. J., Retroactive inhibition as a function of degree of generalization between tasks, J. exp. Psychol., 1941, 28, 93-115)*

The Course of Identification Learning

Typical of studies of identification learning are those in which individuals are required to learn the names of a group of "nonsense figures." A learning curve obtained in such a study is shown in Figure 6.10.

Sometimes, the model or scale which must be learned is a spatial one. This is true, for example, for the task of sorting playing cards into four bins, one for each suit, a task often used in experimental studies of learning. Presumably, what the individual acquires in such learning is a map-like model which enables him to identify a particular stimulus shape (diamond, heart, club, or spade) by means of a response to a particular location (determined by the position of the particular bin). His identifications, as measured by his time of responding or by the number of his errors, become more and more sure as practice proceeds. *Reinforcement* is usually provided immediately, since the learner can compare his just-completed sort with the label on the bin.

The factor of *motivation*, important in all kinds of learning, has been studied in a card-sorting task with results as indicated in Figure 6.11. College students in one group were told that their scores were superior to the average, after each of 15 trials on three successive days; students in

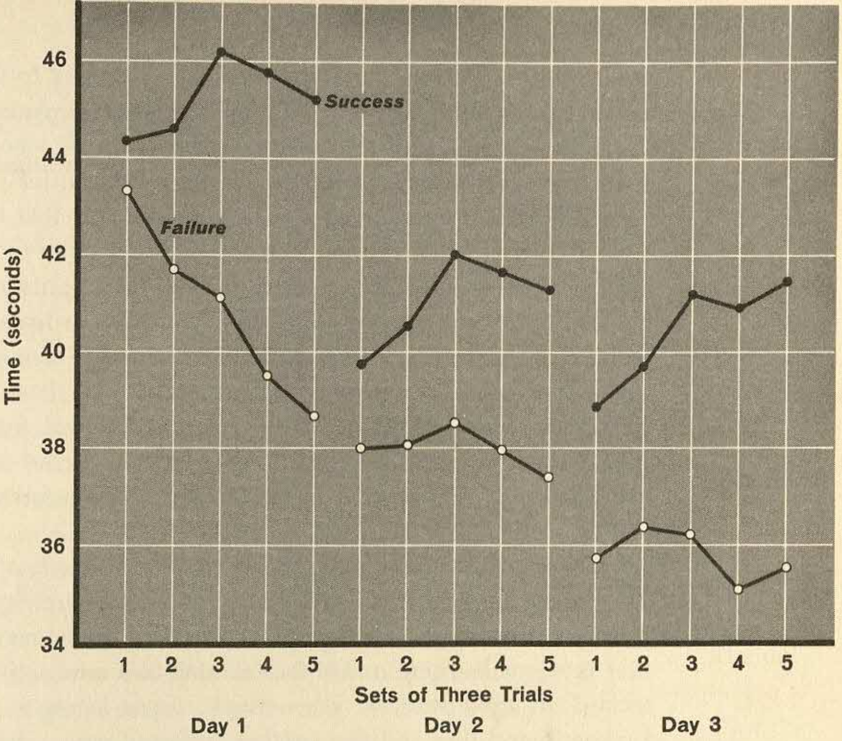


FIGURE 6.11. *Identification learning, measured by reduction in time of card-sorting, in two groups of college men. Individuals in the "success" group were told after each trial their performance was better than average; individuals in the "failure" group that their performance was inferior. (Data from Sears, R. R., Initiation of the repression sequence by experienced failure,* J. exp. Psychol., *1937, 20, 570-580)*

the other group were told their scores were definitely inferior. Although learning occurred in both cases, the amount was quite different. The effect of discouragement by the reporting of "failure" is particularly evident in the increased time of sorting for the students in this group during each set of 15 trials.

TRANSFER OF TRAINING

The basic reason for learning anything is so that we can use the learning in a number of working situations. We learn the whole set of verbal habits and sequences of a foreign language, not so that these can simply be parroted back in an examination, but so that they can be used to read new material or to converse in the language. The ultimate effectiveness of any learning, therefore, is to be found in the answer to the question, "To what extent does the learning *transfer* to a new situation?" Common examples of transfer may easily be found. Practice on a putting green transfers to the activity of putting on any golf course. Learning to fly a small airplane aids in subsequently learning to fly another larger airplane.

The importance of transfer is recognized in all schools. Educators are acutely aware of the necessity of "teaching for transfer"; in other words, of arranging school learning situations in such a way that there will be maximum transfer of the learning to real-life situations or to further learning in advanced courses. Some modern lessons in arithmetic are likely to be phrased in terms which describe life-like problems such as balancing a bank account, or paying the grocery bill. The attempt is made to increase the transfer of school learning to activities that will later take place in the workaday world. However, it is sometimes argued that in stressing this goal, writers of texts in arithmetic may have neglected some of the "fundamentals," that is, the kind of arithmetic which most readily transfers to further study of mathematical subjects.

Transfer of training is the effect on a new activity of previous learning. The extent to which the learning or doing a new activity is made easier by previous learning is called *positive transfer*. Sometimes, it can be shown that previous learning makes the learning of a new activity harder. This is termed *negative transfer*. For example, if one learns to type on a standard keyboard, and then shifts to another keyboard with a different arrangement of keys, the previously learned key-striking habits will *interfere* with the new ones. Such interference may show up, in early trials with the new keyboard, as an unusual number of errors. However, if the effect persists so long that the new keyboard is actually harder to learn than it would have been without the previous skill on the standard keyboard, we have an instance of negative transfer.

The Measurement of Transfer

The amount of transfer (positive or negative) is measured as the difference between the performance of an activity with previous learning and the performance of this same activity without previous learning. Suppose we have two groups of individuals, A and B, whom we know to be equivalent in their initial ability to perform Task Y. We are interested in discovering the degree to which the learning of Task X will help or hinder (transfer to) the later learning to full competence of Task Y. We then can arrange an experimental situation like the following:

Group A	Group B
Learns Task X	Does not learn Task X
Learns Task Y	Learns Task Y

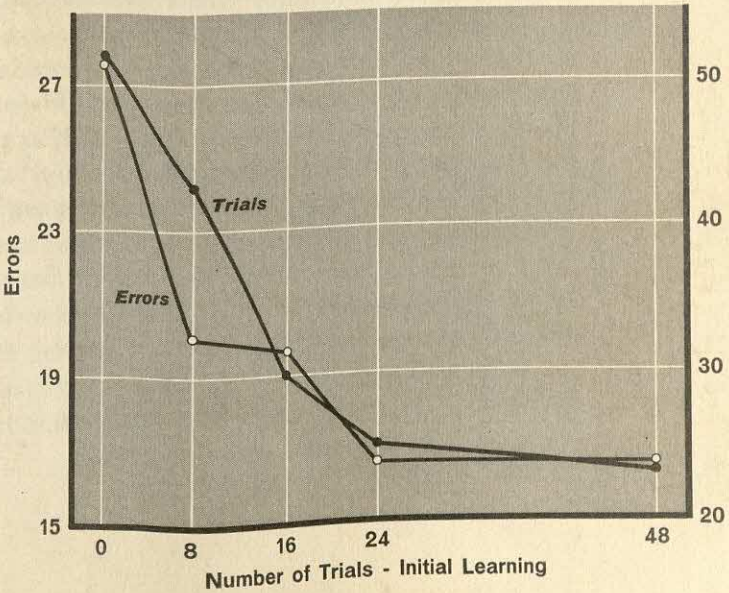
Now, suppose it takes Group A 5 trials of practice to acquire competence in Task Y, and Group B takes 20 trials to attain the same competence. The amount of training saved in Group A is 15 trials; in other words, transfer has contributed 15/20 of the total competence, or 75 percent.

A Typical Transfer Experiment

An illustration of some typical results in the measurement of positive transfer is provided by an experiment in which the final task was learning to make four different identification responses, pressing four different switches to four different light signals. The switches were on a panel resting on a table. They were arranged so as to be equidistant from the observer, with one far-left, a second near-left, a third near-right and a fourth far-right, as the individual sat facing the panel. The task to be learned was to press each of these switches as quickly as possible, on the appearance of a light signal on a vertical panel. The four signals were an upper and lower green light and an upper and lower red light, which had no "natural" spatial relationship to the four switches.

In order to provide a basis for measuring transfer, one group (the "control group") was given no previous training. Other groups were given different amounts of practice on an initial learning task. This task was not the panel itself, but was a printed representation of it, in which pictures of the red and green signal lights appeared in their proper positions, and the individuals were required to make a pencil mark in one of four positions

FIGURE 6.12. *Total errors and trials to 70 percent mastery in the learning of a 4-switch–4-light identification task, as a function of amount of initial practice on the printed representation of this task. Points on the graph represent averages obtained for 29 individuals. (After Gagné, R. M., and Foster, Harriet, Transfer to a motor skill from practice on a pictured representation,* J. exp. Psychol., *1949, 39, 342-355)*



indicating the switch to be pressed. In this experiment, the purpose was to measure the extent of transfer to a switch-pressing task from initial practice on a "picture" of this task. Different matched groups of individuals were given 8, 16, 24, and 48 trials of practice on this initial task, while a control group had no practice on it. Learning of the panel task with four switches and lights was then practiced for 60 trials. Figure 6.12 shows the results obtained for each amount of initial-task practice, in terms of errors made during learning of the final task, and in terms of number of trials required to attain 70 percent mastery. These data show that amount of positive transfer increases with amount of initial practice, in a negatively accelerated fashion. The greater the amount of initial learning, the fewer the number of errors which occurred on the final task, and the fewer the number of trials required to learn it.

The Bases of Transfer

As we have pointed out, transfer is a very common occurrence. In fact, learning is the important process that it is largely because of transfer. When we acquire a new habit, skill, model, verbal sequence, or concept, the learning which takes place is truly effective only because this behavior can be exhibited in a variety of new situations which resemble the learning situation itself to a greater or lesser extent. If the effects of learning were confined to specific situations, human behavior would indeed be limited in scope.

Why does learning transfer beyond the specific situation? What factors account for transfer, and how do these limit the extent to which it occurs? The basic rule is, of course, that transfer between two situations occurs to the extent that they are *similar*. But there are a number of ways in which an initial learning situation may be similar to a later learning (or performance) situation. Some of the best-known ones will be described here.

STIMULUS SIMILARITY. When a simple habit is acquired a connection is established not only between the specific stimulus and the response, but also between physically similar stimuli and the same response. The strength of response to these similar stimuli is smaller as the stimulus becomes less and less similar. When conditioned galvanic skin reflexes were established in human individuals to a tone of 1,000 cycles per second, it was found that responses of lesser strength could be obtained to tones of less than, and to tones of more than, 1,000 cycles. As the tone moved away from 1,000 cycles, the strength of response was progressively reduced. Figure 6.13 illustrates these results, obtained by combining data from instances which employed a number of different tones as the conditioned stimulus.

This phenomenon, which has been demonstrated in animals and men

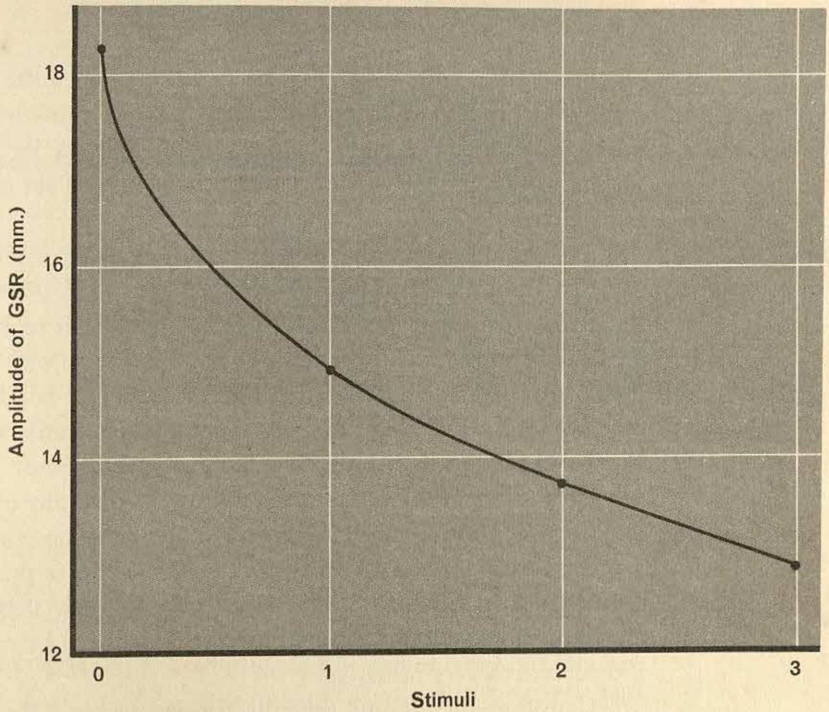


FIGURE 6.13. *Stimulus generalization in the conditioned galvanic skin reflex. The conditioned reflex had a measured strength of 18.2 millimeters to the original tone (shown as zero). The reflex was also exhibited, in diminishing strength, to tones removed from the original one by 25, 50, and 75 just noticeable differences (points 1, 2, and 3 in the graph). (Data from Hovland, C. I., The generalization of conditioned responses: I. The sensory generalization of conditioned responses with varying frequencies of tone,* J. gen. Psychol., *1937, 17, 125-148)*

with a variety of kinds of simple habits, is called *stimulus generalization.* When a learned response is acquired to a stimulus, the individual reacts also, with decreasing response strength, to stimuli having diminishing physical similarity to the original stimulus. Stimulus generalization plays a part in most instances of transfer.

COMMON IDENTICAL ELEMENTS. Another condition which determines the amount of transfer is the number of features or "elements" held in common by the initial learning task and the task to which transfer occurs. This principle applies with particular clarity to the learning of models and scales, in which the "elements" are the individual identification responses. The greater the number of common identification responses between the initial and final tasks, the greater is the transfer of training.

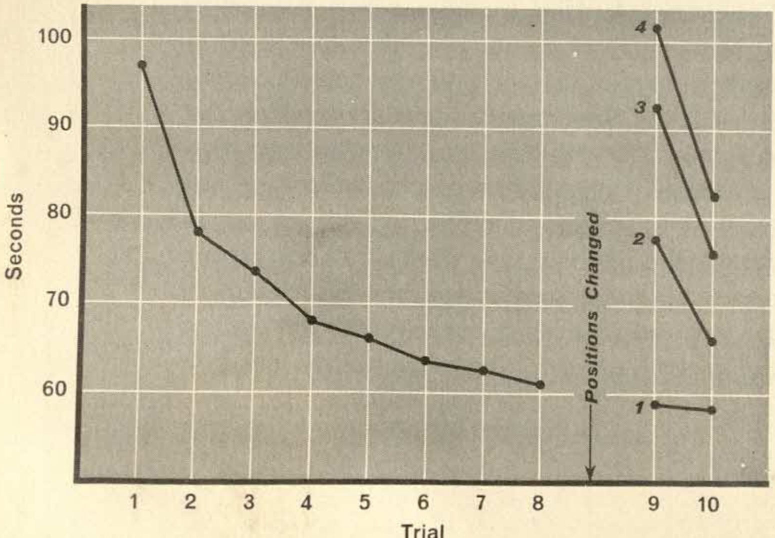
Some typical results are illustrated in the following experiment. Individuals first learned to sort packs of Flinch cards (numbered from 1 to 10, with the number 9 removed) into nine compartments of a sorting box. The time taken to sort the pack completely was measured during eight practice trials. Following this, one group continued the same task for two more trials; a second group undertook to learn a task in which the sorting positions of 3 out of the 9 numbers were changed; for a third group, the sorting positions of 6 out of 9 were changed; and for a fourth 9 out of 9 were changed.

We should expect the first group to continue to show some improvement on these final two trials, since they are simply continuing to learn the same task. In other words, 100 percent transfer is to be expected in this group. When the identical elements are 6 out of 9 (with 3 changed), transfer should be less, and so on until the condition of no identical elements is reached (9 out of 9 changed), when no positive transfer would be expected. Figure 6.14 shows that this is essentially what happened.

Concepts. Perhaps the most striking effect on any condition of transfer is observed when a concept learned in one situation is used in performing a second task. When an individual learns a rule or principle, as we have pointed out in Chapter 3, he is then able to apply it to a variety of new situations immediately. Transfer which is mediated by concepts is typically 100 percent or very nearly so.

Consider, for example, the six nonsense figures shown in Figure 6.15. The three on the left are called ZIF, and the three on the right are Not ZIF. The identification of each of these figures could readily be learned by means of traditional practice methods. Following this, the individual would be able to transfer these identification responses to a new set of figures, to

Figure 6.14. *Transfer as related to the number of common elements in the initial and final tasks. All groups first practiced sorting nine Flinch cards (numbered 1 to 10, with number 9 removed) into nine compartments of a sorting box. Following this, group 1 continued the same task; group 2 sorted with 3 out of 9 sorting positions changed; group 3 with 6 out of 9 changed; and group 4 with all changed. Positive transfer is shown to decrease progressively in these groups. (Data from Crafts, L. W., Transfer as related to number of common elements, J. gen. Psychol., 1935, 13, 147-158)*



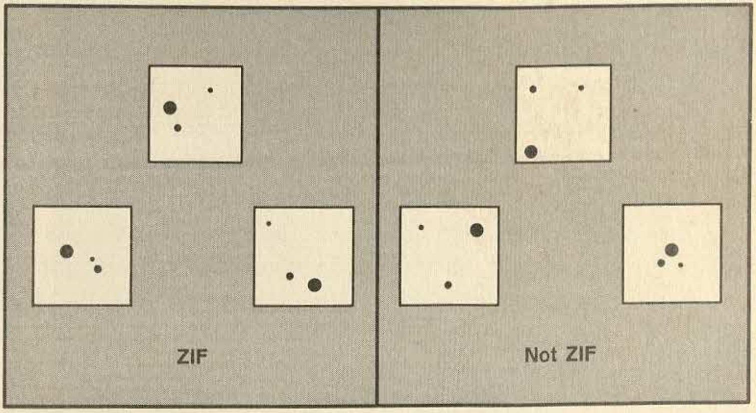


FIGURE 6.15. *Examples of figures which may be identified after learning models, or alternatively, after learning a concept (rule). The figures on the left are ZIF, those on the right Not ZIF. (After Smoke, K. L., An objective study of concept formation,* Psychol. Monog., *1932, 42, No. 4)*

an extent determined by stimulus similarity, and by the number of identical elements held in common. But suppose instead we teach him "A ZIF has three dots. The distance between the two uppermost dots is twice the distance between the two lowest ones." What a remarkable change in his behavior will be brought about when he acquires this concept! Now, he will be able to identify an endless variety of specific figures as ZIF or as Not ZIF, without any appreciable error. The rule enables him to achieve 100 percent transfer in any specific new situation.

A classic experiment provides another example of the importance of concepts in transfer.[3] Groups of boys were given practice in shooting targets under water. One group was first instructed in the principles of light refraction, that is, they learned the rule that the target would appear displaced from its real position because of refraction. The other group was not given this instruction. Both groups first practiced shooting at a submerged target until they had learned equally well. Then the depth of the target was changed. The first group, using the refraction concept, quickly learned to hit the target at its new depth, while the second group required extensive further practice. Again, these results show the remarkably high degree of transfer which occurs when concepts are employed.

RETENTION

We have seen that a marvelous variety of skills can be acquired by a process of learning and stored as "action programs" to determine the kinds of behavior exhibited in identification, reciting verbal sequences, performing motor skills, and solving problems. It is the memory function which makes it possible for man to profit by experience, so that he typically acquires higher and higher levels of ability, and more and more varieties of skills, from birth onward.

But we also know that there is some loss of these specific stored programs over a period of time. Retention is not perfect, as it would be in a machine that was not subject to physical deterioration. The weight of evidence indicates that losses in retention occur because of some dynamic neural events that take place over time, and not because of physiological degeneration. (Of course, age does bring about such degeneration, and old people tend to have poor retentive capacities, but that is another story.) In all probability, forgetting is nearly as important to man's working behavior as is learning. It is a remarkably useful capacity, not one which detracts from man's capabilities. Forgetting is what makes it possible to begin the learning of new habits and skills without having always to unlearn old ones. And since the demands of life are such that human beings must learn new things constantly, it is very convenient that old habits are lost. Forgetting makes man more flexible, more readily adaptable to new situations.

The Course of Forgetting

We can illustrate the basic facts about forgetting, or its opposite, retention, with some data obtained in the runway situation with white rats. Several groups of these rats learned the habit of running from the starting box in a number of trials, until they were making each of three successive responses in five seconds or less. Then they were returned to their usual cages. One set of rats was put back in the learning situation after three days; another set after seven days; a third after fourteen days; and a fourth after twenty-eight days. For each rat, the number of practice trials was noted for him to reach again the level reached during the original learning (each of three successive responses in less than five seconds). These results give us an idea of how much was retained, or conversely, how much forgotten following these intervals of time. Figure 6.16 shows what was found. The general relationship is: *Forgetting increases in a negatively accelerated fashion with the passage of time.* Most forgetting occurs in the period immediately following initial learning.

Conditions of Forgetting

Measurement of the course of forgetting of verbal materials was first undertaken by Ebbinghaus in 1885. He learned lists of nonsense syllables

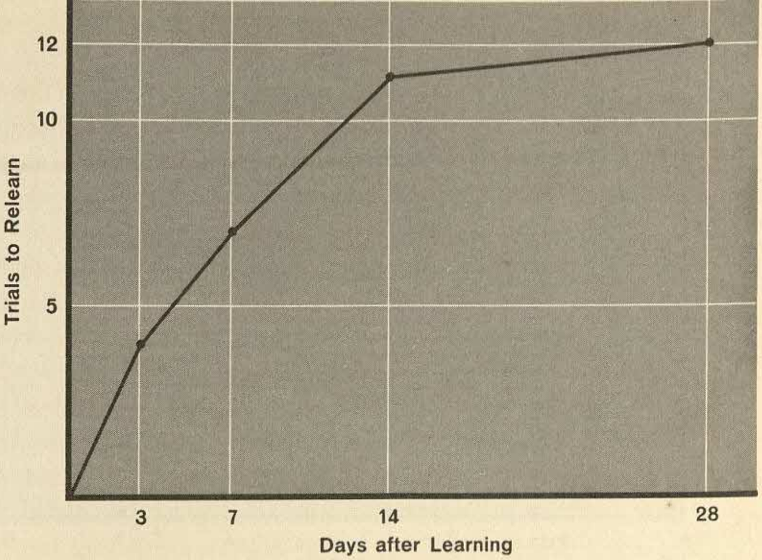


FIGURE 6.16. *The forgetting of a simple habit. The points on the graph represent the average number of trials required for groups of four white rats to reach, in relearning, the point of making each of three successive responses in less than five seconds, after having learned the habit originally to this same degree. Forgetting is often expressed as a percentage of trials to relearn / trials to learn. In this experiment, technical reasons prevented the determination of the latter quantity. However, forgetting of this habit was estimated as being nearly complete after 28 days. (After Gagné, R. M.,* The retention of a conditioned operant response, J. exp. Psychol., *1941, 29, 296-305)*

until he was able to recite them perfectly once, then waited a number of days, and measured the number of trials required to relearn these same lists. The difference between number of trials to relearn a given list and the number of trials required for its original learning was taken as a measure of "savings due to retention."

For the verbal sequences with which he worked, Ebbinghaus found a rapid and extensive forgetting during the first few hours, followed by forgetting at a slower rate extending over several days. His results are shown in Figure 6.17. This curve in its general form provides a prototype for all curves of retention. We see again that forgetting follows a negatively accelerated course. However, there are a number of other conditions which determine how rapidly forgetting takes place, and what its final level is.

Methods of Measuring Retention

In measuring retention, the two major methods which may be distinguished are those of *recall* and *recognition.* In recall, we ask the individual to reinstate previously acquired responses to the same stimuli which were present when he originally learned them. This is the usual method

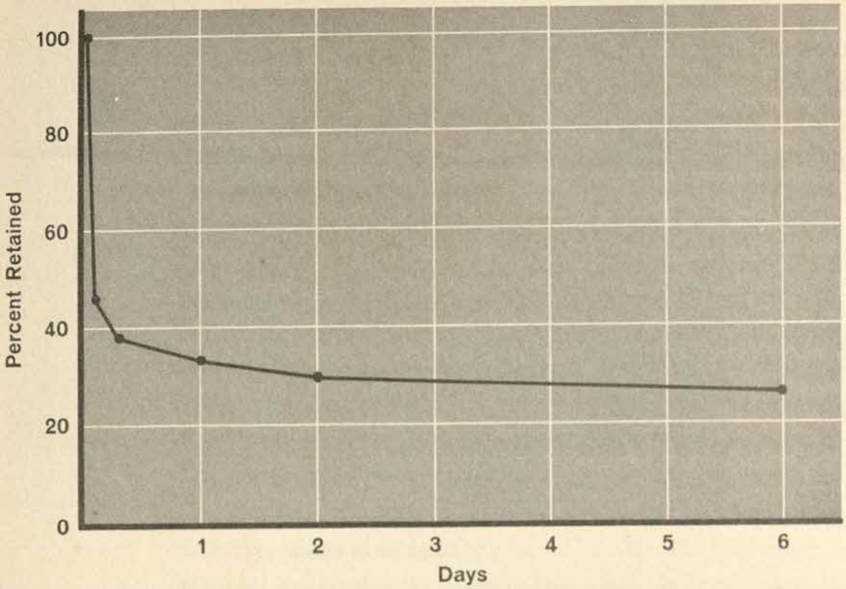


FIGURE 6.17. *The curve of retention for sequences of nonsense syllables, as reported by Ebbinghaus. (After Ebbinghaus, H.,* Memory: A contribution to experimental psychology *(Trans. by Ruger, H. A., and Bussenius, C. E.), Columbia Univ. Coll. Educ. Reprints, No. 3. New York: Teachers College, Columbia University, 1913)*

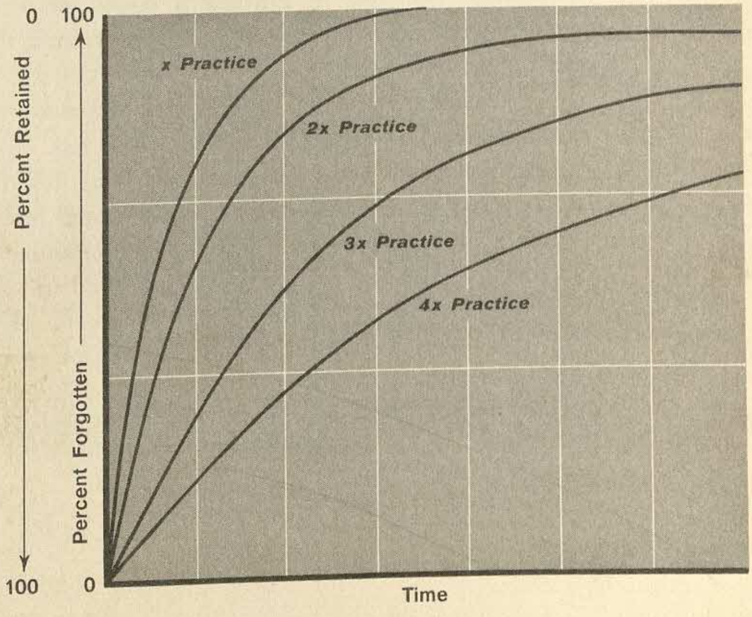
employed, for example, when we ask an individual to recite or write down previously learned verbal habits. However, even when he may have forgotten a high percentage of these habits, we may still be able to demonstrate retention for these "forgotten" items by asking him to *recognize* them. In recognition, the individual is simply asked to distinguish those stimuli he has responded to previously (in a given situation) from those he has not. Having forgotten ten out of twelve new foreign words, in the sense of being unable to recall them, the individual may still be able to distinguish these words from others he has never heard before. Thus, when retention is measured by recognition, it is typically much greater than when measured by recall. "I remember your face, but I can't recall your name," is a common statement which expresses this contrast between recognition and recall. *Recall* may be expressed simply as amount retained. For example, in studies of verbal sequences, we sometimes find the measure "Number of syllables recalled." Another frequently used measure is based upon the number of trials required to *relearn* some previously learned task. If the original learning required 20 trials for mastery, and the relearning (after a period of forgetting) only 8 trials, one can say that the "savings" due to retention was 12 trials. Frequently, this "savings" is expressed as a percentage of the number of trials originally required for learning. In the example given, percent savings = 12/20 = 60 percent. Thus, if retention is high, percent savings will be high, and if retention is poor, percent savings will be low.

The Effect of Overlearning on Forgetting

When a habit, skill, or verbal sequence is practiced, we have seen that it eventually attains some performance level which is either arbitrarily called "adequate," or which is improved upon only very slowly by additional practice. However, such additional practice, even though it may have a small or unmeasurable effect on the level of performance during learning, may nevertheless show its effects in slowed forgetting. A number of studies of verbal-sequence learning have shown that *retention increases with the amount of original practice.* The interesting thing is that this relationship holds true far beyond the point at which increases in perfection of the originally learned performance can be measured. The general nature of the relationship is shown in Figure 6.18. *Overlearning* is the term used for practice continued beyond that required for some adequate level of performance.

Obviously, overlearning is a very important factor in the retention of all kinds of learned activities. It is incorrect to assume that because two individuals show the same level of performance on any given occasion, they will retain this activity equally well. A recently trained pilot, and one with ten years of experience, may be equally able to pass a test of adequate performance in an aircraft. If both discontinue their flying after this test, which will be able to display the better performance two years later? Because the experienced pilot has had much overlearning, we should expect his retention of skill to be considerably better than that of the newly trained pilot.

FIGURE 6.18. *Family of theoretical curves showing the effect of amount of original practice on forgetting. According to results obtained in the learning and retention of verbal sequences, increasing the number of trials of original learning decreases the rate of forgetting. Note that all curves begin from the point of 100 percent retention (or 0 percent forgetting) at 0 time.*



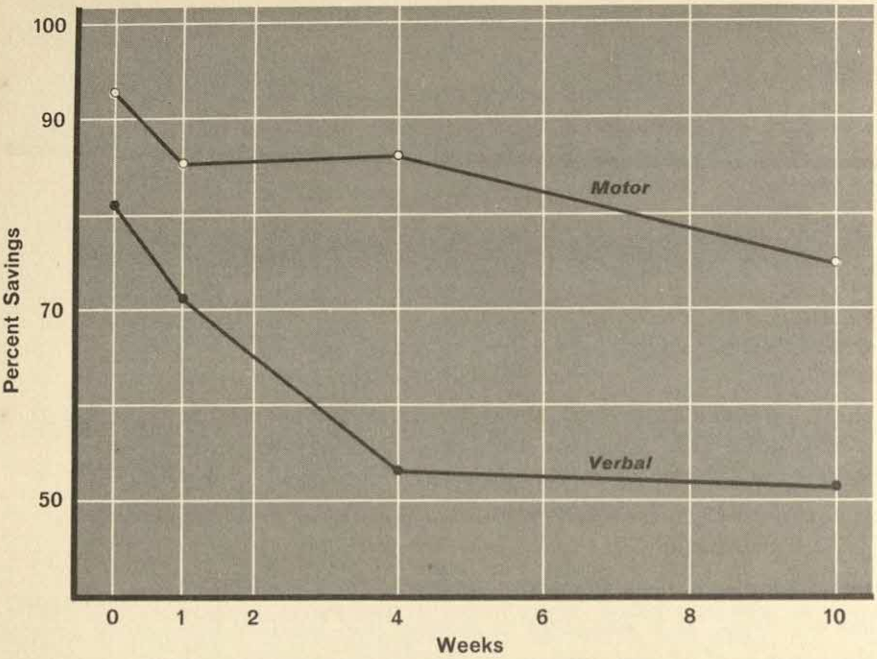


FIGURE 6.19. *Comparison of retention of a motor task and a verbal sequence of 15 nonsense syllables. The mean savings at each interval was obtained by comparing the retention score of each individual with the score on his last learning trial. (After Leavitt, H. J., and Schlosberg, H., The retention of verbal and of motor skills, J. exp. Psychol., 1944, 34, 404-417)*

Nature of the Retained Activity

Different kinds of activities (habits, skills, verbal sequences) are apparently forgotten at different rates. It is difficult to find a way of stating this relationship precisely, because we are not certain how to compare initial levels of adequacy (and therefore amounts of overlearning) for such disparate activities as learning a poem and riding a bicycle. However, when reasonable attempts are made to control the level of initial practice, the rates of forgetting of different activities still show large differences.

The contrast in rate of forgetting of a motor skill and a verbal sequence is illustrated in Figure 6.19. The motor task in this study was the pursuit rotor (similar to the Rotary Pursuit Test described in Chapter 5) which was practiced for ten consecutive 30-second trials with 30-second rests between them. The verbal task was the learning of a sequence of 15 nonsense syllables, and this was also practiced in ten 30-second trials with the same length of rest period. Thus the amount of practice was equated, and in this sense the amount of learning can be considered equivalent. As the figure shows, however, the motor task was forgotten less rapidly, and a considerable difference in the level of retention of the two tasks remained throughout several weeks.

Summarizing the evidence from a number of studies, it appears that the kind of human activities most resistant to forgetting are motor skills of the type which are continuous rather than discrete. As we all know, activities like skating, swimming, or riding a bicycle stay with us for many years even though there may be no intervening practice. Concepts also tend to be retained well for long periods of time, to judge from the evidence of studies of retention of the meaning of prose materials. Models and scales probably occupy an intermediate position so far as rate of forgetting is concerned, though evidence on this point is scanty. Most rapid forgetting occurs with verbal sequences (particularly meaningless ones) and simpler verbal habits. It should be borne in mind, however, that the retention of any specific activity in everyday life is dependent more upon two conditions than upon inherent differences in the activities themselves. These conditions are (1) amount of initial practice, and (2) amount of rehearsal which may intervene between original learning and a subsequent test of retention. Retaining the ability to play the piano or to recite a poem may, in any particular instance, be largely dependent upon the fact that the activity was overlearned to begin with, or upon the occasional rehearsals that have occurred over a period of years.

The Nature of the Forgetting Process

What kind of internal process takes place in forgetting? Is it a simple decay with the passage of time, or an active erasing process? So far as we can tell now, it is probably both, but the latter concept of active erasing can be shown to account for a very large part of forgetting.

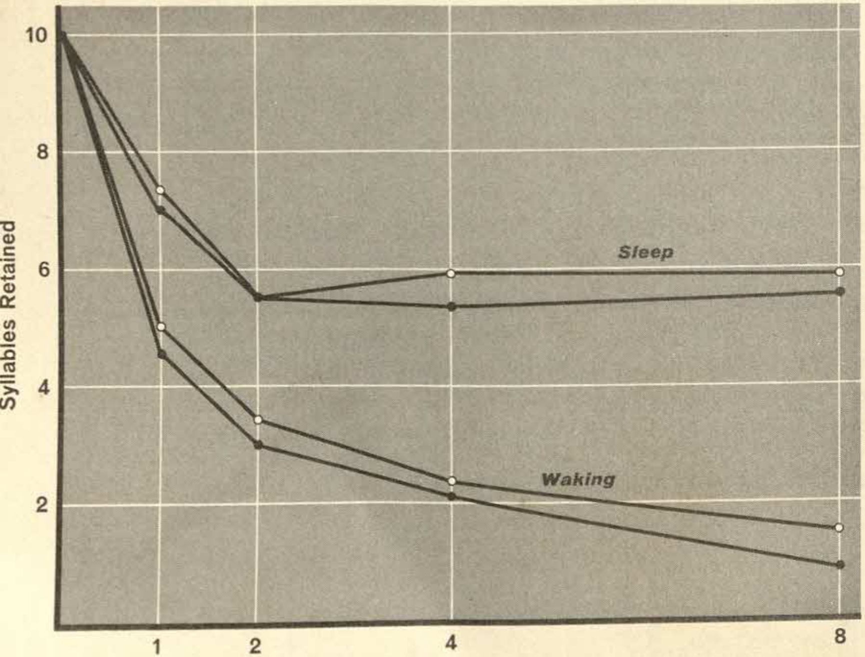
INTERFERENCE. Many studies have shown that the retention of an activity is interfered with by the learning of a subsequent activity which is similar in some respects to that first learned. For example, if individuals learn one sequence of nonsense syllables, and are then set the task of learning a second sequence, it may be shown that their retention of the first sequence has been interfered with by the learning of the second. This phenomenon, called *retroactive interference*, may be demonstrated by having a second group of individuals of equivalent ability learn the first sequence, *not* learn the second, and recall the first sequence after the same time-interval as does the first group. When such an experiment is performed, the second group of individuals retains the original sequence better than the first group. The amount of interference produced by the intervening learning increases as the original and interfering tasks are made more similar to each other.

In addition, it has been shown that the greater the amount of practice on the original task, the less susceptible it is to interference by a second learning task. People who study two foreign languages at the same time report the frequent occurrence of retroactive interference. Often, the original task (that is, the foreign words learned first during any one day) is not extensively practiced and is therefore highly subject to interference by the learning of a second set of foreign words. On the other hand, when the vocabulary of one foreign language is well established, the tendency for interference by learning a second foreign vocabulary is much reduced.

Recent studies have demonstrated that retention is also markedly affected by *proactive interference.* The retention of a verbal sequence of nonsense syllables, for example, is reduced in accordance with the number of verbal sequences learned *just prior* to the learning of the list whose retention is being measured. Thus interference works both proactively and retroactively to reduce retention.[4]

Forgetting and Inactivity. Since a human being is constantly active in the sense that he is always learning something new, it should be possible to reduce retroactive interference, and thus increase retention, by reducing the amount of activity which he engages in after learning. Several studies have shown that this is indeed the case. Figure 6.20, for example, shows what happened to the retention of sequences of ten nonsense syllables in two individuals when they went to sleep immediately after learning, and when they stayed awake. Retention of these sequences was measured after 1, 2, 4, and 8 hours of sleep, and after the same amount of time awake.

FIGURE 6.20. *The retention of sequences of 10 nonsense syllables by two individuals fter varying amounts of sleep immediately following learning. (Data from Jenkins, . G., and Dallenbach, K. M.,* Obliviscence during sleep and waking, *Amer. J. Psychol., 1924, 35, 605-612)*



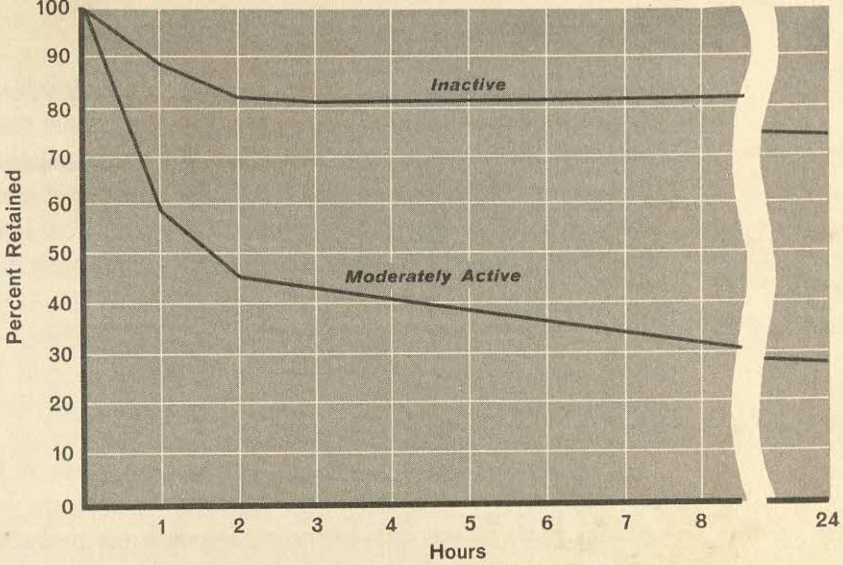


FIGURE 6.21. *Retention of a simple avoidance habit in cockroaches. One group was maintained in an inactive state, the other was moderately active. (After Minami, H., and Dallenbach, K. M., The effect of activity upon learning and retention in the cockroach,* Amer. J. Psychol., *1946, 59, 1-58)*

Note that after two hours, when sleep can be considered to be quite sound, forgetting appeared to be practically nonexistent in these two individuals.

It is difficult to reduce the level of activity to zero in human beings immediately after learning, because they do not go to sleep immediately, and the first minutes of sleep are not very deep. Drugs can be used to induce rapid sleep, of course, but then we would not know what the direct effects of these drugs on the forgetting process might be. Because of this, it seems impossible with human beings to determine exactly the extent to which forgetting is caused by interfering activity.

It has been possible, however, to investigate this question with an animal that may be made immobile directly following learning. This animal is the cockroach. These insects first learned the simple habit of avoiding the darkened end of a lighted alley in an experimental apparatus. This was done by giving each animal an electric shock whenever he entered the dark end. On the average, 15 to 18 practice trials were required for these animals to learn this avoidance habit. Each animal in the "inactive" group then crept into a narrow cone lined with soft material, where he remained for hours in an immobile sleep-like state. Animals in the "active" group were simply transferred to a round cage where they continued to be moderately active during the retention period. Figure 6.21 shows the remarkable difference in retention of these two groups of cockroaches. Forgetting was much more rapid in the active animals. However, some forgetting occurred in the animals who were made immobile after learning. Apparently, then, retroactive interference or some similar active erasing process is responsible for a great deal of forgetting, but not for all of it. To some extent, retained activities simply decay with the passage of time. From these results, it looks as though this process of decay takes place during the first few hours, whereas the process of active interference goes on for a longer time.

SUMMARY

Human beings are able to increase the level of their performances through a process called *learning*. This is a process by means of which stimuli come to act with increasing strength (or probability) as signals for responses. Although the physiological and neural conditions for learning are not well understood at present, the *external conditions* which bring about this heightening of skill can be described in some detail.

The simplest type of acquired connection between a signal and a response is called a *habit*. The learning of habits is not easy to study in a pure form in human adults, because they already possess so many learned habits. Consequently, habit-acquisition is often studied by using *children*, *animals*, or a rather special form of habit called a *conditioned reflex*.

Simple-habit learning is measured as a progressive increase in strength of a response. It occurs under the following conditions: (1) The individual must be *motivated*. (2) There must be the attainment of a goal or reward, called *reinforcement*, following each signal-response sequence. (3) There must be one or more *repetitions* (*practice*) of the signal-response-reinforcement sequence. (4) The situation must be *free from emotional interference*.

Habits are subject to *experimental extinction*, an active erasing process which occurs when reinforcement is omitted. According to one modern theory, extinction is produced by an internal process of *inhibition*.

The learning of *motor skills* is a process of chaining together sequences of simple habits. The individual responses which make up the sequence may be identifiable as *discrete* units, or they may form a *continuous* activity. In any case, the conditions of learning are found to be basically the same as those described for habits themselves. The increase in attainment of skill may be measured as *increase in accuracy*, *increase in the number of correct responses*, *decrease in errors*, or some combination of these.

The conditions for learning may also be demonstrated and studied in *learning verbal sequences*, and in *identification learning*. In both of these types of learning, the difficulty of the task is strongly affected by *interfer-*

ence, that is, by the tendency of the signal to acquire connections with responses other than the correct one, and thus to block the latter connection.

Transfer of training is the effect of previous learning on a new activity. When the new learning is made easier, the effect is spoken of as *positive transfer;* when it is made harder, we have *negative transfer.* Positive transfer has been shown to increase with the *amount of initial-task learning.* It also depends upon the *stimulus similarity* between the initial and final tasks, or upon the presence of *common elements* in these tasks.

The process of forgetting takes place rapidly at first, then more and more slowly with the passage of time. Retention is typically measured by a test of *recall,* which asks the learner to reinstate learned material, or a test of *recognition,* in which he is asked simply to identify previously learned material. Retention increases with the amount of initial practice; this relationship holds even though the practice proceeds beyond the point of mastery, in *overlearning.* Forgetting is influenced by the nature of the task learned; motor skills appear to be forgotten slowly in comparison with verbal habits and sequences. *Interference,* both *proactive* and *retroactive,* has marked effects in reducing retention. Studies have shown retention to be increased when animals are immobilized immediately following learning; in human beings, sleep has a similar effect.

READING REFERENCES

Bugelski, B. R., *The psychology of learning.* New York: Holt, 1956. A textbook.

Deese, J., *The psychology of learning.* New York: McGraw-Hill, 1952. A textbook.

Hilgard, E. R., *Theories of learning.* (2nd Ed.). New York: Appleton-Century-Crofts, 1956. An account of the major theories of learning, including related experimental studies.

McGeoch, J. A., and Irion, A. L., *Psychology of human learning* (Rev. Ed.). New York: Longmans Green, 1952. A systematic summary of findings from studies of human learning.

Stephens, J. M., *Educational psychology.* New York: Holt, 1951. The principles of learning applied to educational problems.

Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954. A textbook of experimental psychology including considerable material on learning and retention.

7

DISCRIMINATION AND IDENTIFICATION

The external physical world makes its impression on the human individual through his senses. Detecting differences in stimulation is a matter of discrimination. The nature and limits of this kind of behavior are described in this chapter. The organization of sensory data into colors, sounds, shapes, distances, and objects is exhibited by the human being in a kind of behavior known as identification, which depends largely on the learning of internal models and scales. Some of the important kinds of identification, and the factors which influence them, are described here.

Human beings are sensitive to many different kinds of stimulation from physical energy in their environments. We have already seen that the possession of differentiated sense cells, similar in most respects to those of other animals, makes the human being capable of detecting stimuli through the various receptors for vision, hearing, touch, pain, temperature, smell, taste, and kinesthesis. The inputs provided by these stimuli are the basis of all behavior; we cannot imagine organized response-outputs except against a background of an environment that affords the individual a constant bombardment of stimulation varying within certain definable limits.

In this chapter we will take a more intensive view of two aspects of man's behavior which we identified as basic functions of the behavior system in Chapter 3. First, we shall look at *discrimination*, the ability that is exhibited when an individual makes a response indicating that he can tell the difference between two physical stimuli. We shall want to examine man's capacity for making such discriminations, for each of his senses, and for each kind of stimulus variation, insofar as this is known. Second, we shall give a more detailed account of the learned skill called *identifica-*

tion, the acquiring of models and scales which makes possible the production of differential responses to two or more stimuli in a set. How are these skills acquired, and what kinds of identifications can be learned within the various categories of physical stimulation?

A Word about Terminology

It should be mentioned that in speaking of discrimination and identification, we are using words that are understandable to psychologists, but are not conventional in elementary texts. For many years, behavioral scientists held a set of concepts somewhat different from those described in Chapter 3. These concepts divided the input side of human functioning into *sensation* and *perception*, both of which were thought of as giving rise to states of consciousness, but not necessarily to observable responses. Later on, it was found necessary to conceive of human functioning in a way which included overt response-outputs as the primary indicators of behavior. The words *sensing* and *perceiving* are still used in present-day conceptions, to identify the inferred internal (neural) processes which precede the action of effectors in responding. These terms are roughly equivalent to *discrimination* and *identification*. We occasionally use them in this way in the present chapter, although we believe that discrimination and identification are preferable terms. Although the latter obviously relate to sensory inputs, they place emphasis on what the human being does about these inputs.

DISCRIMINATION

In observing and measuring human discrimination, we are interested in determining the least change in physical energy impinging on a receptor to which the individual can respond. There are two different ways in which a "least change" might produce a differential response. The first depends simply upon the presence or absence of a stimulus. Light waves may be made to strike the eye at such a low level of energy that they cannot be responded to at all. Raising the intensity of this stimulus, we arrive at a point at which a response is given. This minimum amount of stimulation which can produce a "yes" rather than a "no" response is called the *absolute threshold.* It is defined as the value of the physical stimulus which is detectable 50 percent of the time, and not detectable 50 percent of the time. The total expression of absolute threshold for light intensity would of course describe the least detectable intensity of light throughout the entire range of wave lengths from infra-red to ultra-violet.

The second type of "least change" refers to the change in physical energy required for two stimuli to be responded to as "different" rather than "the same." This is called the *differential threshold.* It is usually expressed as the small amount of change, ΔX, required to produce the differential response, with reference to a specific value of the stimulus X. Suppose, for example, we have blue light of wave length 470 millimicrons (abbreviated $m\mu$). How much of a change in wave length ($\Delta\lambda$, where λ symbolizes wave length) is needed, added to or subtracted from this basic wave length, for a man to discriminate it? From studies of wave-length discrimination, we know the answer to be 2.0 $m\mu$; that is, $\Delta\lambda = 2.0\ m\mu$.

Very often, this small change (ΔX) is expressed as a proportion of the basic stimulus, or as $\Delta X/X$, particularly when we are dealing with stimulus intensity. Generally speaking, the larger the stimulus-intensity value (I) with which we start, the larger is the value of ΔI. If one can barely discriminate between 16 ounces and 18 ounces, it is reasonable to expect that one can also just discriminate between 16 pounds and 18 pounds. The absolute value of ΔI is considerably larger in the latter instance, but the proportion ΔI/I is the same. However, we shall see that this proportion is *not* the same *throughout the entire range* of stimulus intensities, for any of the senses.

THRESHOLDS. A word should be said here about the concept *threshold,* which we have defined above. The threshold, whether absolute or differential, cannot be determined from a single measurement, since it is influenced by the variability of the behavior system. Instead, the experimenter must take several "readings" and find their median value. Furthermore, he must obtain the individual readings by a bracketing procedure. For example, in finding the absolute threshold for light intensity, he might begin with a light intensity which obviously can be seen and *reduce* it gradually until it is just not seen. The intensity value at this point constitutes one measurement. Next, he begins with a value of intensity which cannot be seen and gradually *increases* it until it can be detected. This value constitutes a second measurement. The threshold itself is not either of these individual measurements. Rather it is obtained by an averaging process, as that value which is detectable 50 percent of the time (or not detectable 50 percent of the time).

There is a great deal of exact information about absolute and differential thresholds for vision and hearing, and somewhat less for the other senses. The engineer who requires such data in the design of equipment for human use should have no difficulty in finding values which fit most of the particular conditions in which he is interested (see Reading References). Here we must be concerned with a general overview of human discrimination capacities, in order to give an idea of what the limits of discrimination are, how they are measured, and what conditions influence them. We shall use visual discrimination to explain some basic concepts, and treat the other senses somewhat more briefly.

VISUAL DISCRIMINATION

Light waves are electromagnetic radiations which make up a very small part of the entire spectrum of radiant energy. The range of the visible part of this spectrum is approximately from 400 mμ (violet) to 700 mμ (red). As we have seen in Chapter 2, such waves reach the sensitive part of the eye by passing through the lens which brings them to a focus on the retina. The retina is composed of sensitive cells called rods and cones, as well as neural fibers and synapses leading from them. Actually, the light passes through this network of visual fibers before reaching the sense cells, so that a certain amount of diffusion occurs. The light decomposes the substance contained in the rods and cones in a manner which can be predicted from photochemical laws, and this process leads to the stimulation of neural fibers. These neural impulses pass through synapses, over the optic nerve, and to the visual cortex in the brain. Here they make the connections which result in a discrimination.

In measuring visual discrimination, certain standard units of light energy are used. One of these is the foot-candle, a measure of the amount of light emitted from a point source of an International Candle. A second common measurement is the amount of light emitted from a perfectly diffusing surface. This is expressed in foot-lamberts (Ft.-L) or more commonly in millilamberts (1 mL = 0.929 Ft.-L). Because of the great range of absolute values which have to be employed, these measurements are often expressed in logarithmic units.

Rod and Cone Vision. The two types of sensitive cells in the eye react in different ways to light. It is possible to arrange stimulation so that only cones (in the center of the retina) or only rods (in the periphery) are affected. By means of such studies, the characteristics of rods and cones can be clearly differentiated. Under conditions of ordinary daylight vision with light falling on the total retina, both types of receptors come into play. The differences between rods and cones may be summarized as follows: Rods function in the discrimination of low intensities of light, and not at all in color discrimination; cones function at high intensities and in color discrimination. A light of 670 mμ wave length is seen as red when looked at centrally. When such light falls outside of the central retina, it is still seen, but loses its color. If we reduce the intensity of this light, it may be seen at the periphery, but not at all at the center of the retina, where the cones are. At twilight, colored objects gradually decrease in brightness and at some point lose their color altogether, because the cones no longer respond to this low level of stimulation. At this point small dim objects are seen because of rod activity, uncolored; if we shift our gaze so that the light from them reaches only the central retina, they disappear because the cones are insensitive to these low intensities.

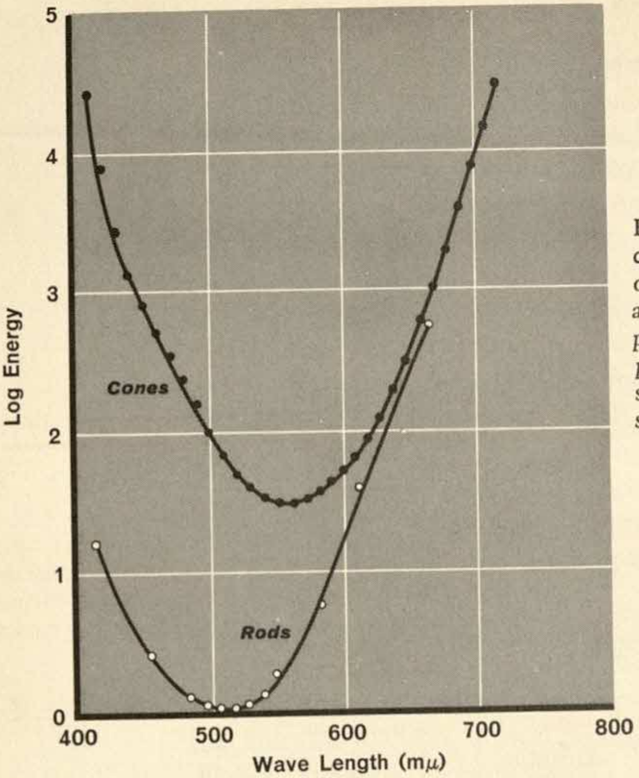


FIGURE 7.1. *Visibility curves for rod and cone vision, indicating the relative amounts of energy needed to reach absolute threshold as a function of wave length. (From Chapanis, A., How we see: A summary of basic principles. Ch. 2 in Human factors in undersea warfare. Washington, D.C.: National Research Council, 1949)*

Absolute Thresholds

When the absolute threshold is measured and plotted throughout the range of wave lengths, the result is known as a *visibility curve.* Such curves for both rod and cone vision are shown in Figure 7.1.

For cone vision, there is maximum visibility in the greenish-yellow part of the spectrum (555 mμ). In contrast, the rods are most sensitive to the green part of the spectrum (510 mμ). In this region, it takes 100 times as much energy (2 log units) for light to be seen as colored by the cones as for it to be detected uncolored by the rods. Notice also from Figure 7.1 the tremendous difference in energy required at absolute threshold for the yellow-green region of the spectrum as well as for the violet end.

ADAPTATION AND THE ABSOLUTE THRESHOLD. In everyday vision, it is apparent that the rods and cones are not always sensitive to exactly the same degree each time they are stimulated. Instead, their absolute threshold varies with the level of surrounding illumination. When we first enter a darkened room, for example, we can see very little; but after half an hour or less we can discriminate many light-differences and distinguish many objects in the room. This is because the sensitive cells of the retina attain a state of equilibrium which corresponds to the general level of illumination, a process called *adaptation.*

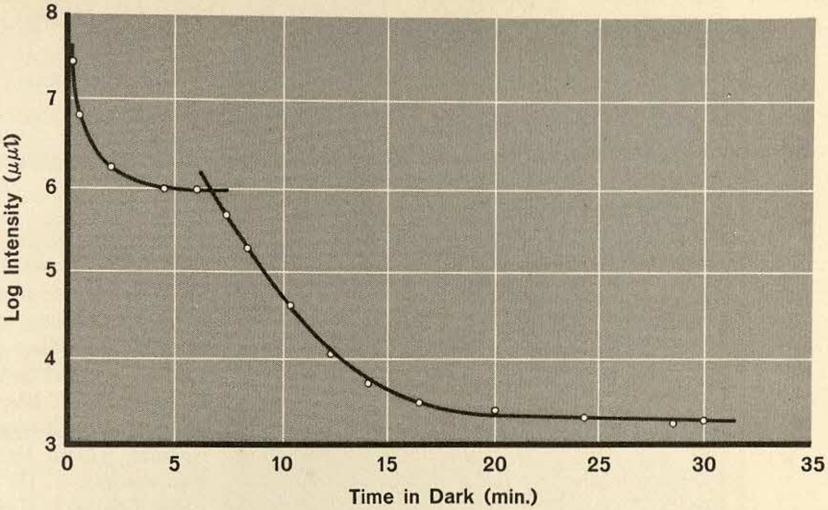


FIGURE 7.2. *Adaptation of the retina to the dark following a high level of light-adaptation. The left portion of the curve is for the cones, the right portion for the rods. These data were obtained for a light of short wave length, below 460 mμ (violet). (From Hecht, S., and Shlaer, S., An adaptometer for measuring human dark adaptation,* J. opt. Soc. Amer., *1938, 28, 269-275)*

The course of dark-adaptation is illustrated in Figure 7.2. As this figure shows, the cones approach a state of adaptation to absolute darkness in a very few minutes, after being plunged into darkness from a previously high level of illumination. The rods take longer, and approach a final level of equilibrium after about 30 minutes. As is apparent, the retina becomes responsive to light that is only 1/100,000 of the intensity originally required, after 30 minutes in the dark.

The retina apparently adapts very quickly to light after coming out of the darkness. A new state of equilibrium is attained in a few minutes when illumination is provided after a period of complete darkness. According to one set of measurements, three minutes is sufficient for light-adaptation to be complete. Longer times, however, are indicated by other methods of measurement.

Differential Threshold

The proportionate increase ($\Delta I/I$) necessary to make possible a discrimination at different base levels of light-intensity is shown in Figure 7.3. Log units are used in order to reduce the scale. From the figure, it is apparent that various wave lengths of light behave differently with respect to discrimination. At the lower intensities, the break between cone and rod functioning can clearly be seen in the curves obtained for orange, yellow, green and blue light. In all cases, however, the curves show clearly that the value $\Delta I/I$ is not a constant. The proportionate increase in intensity

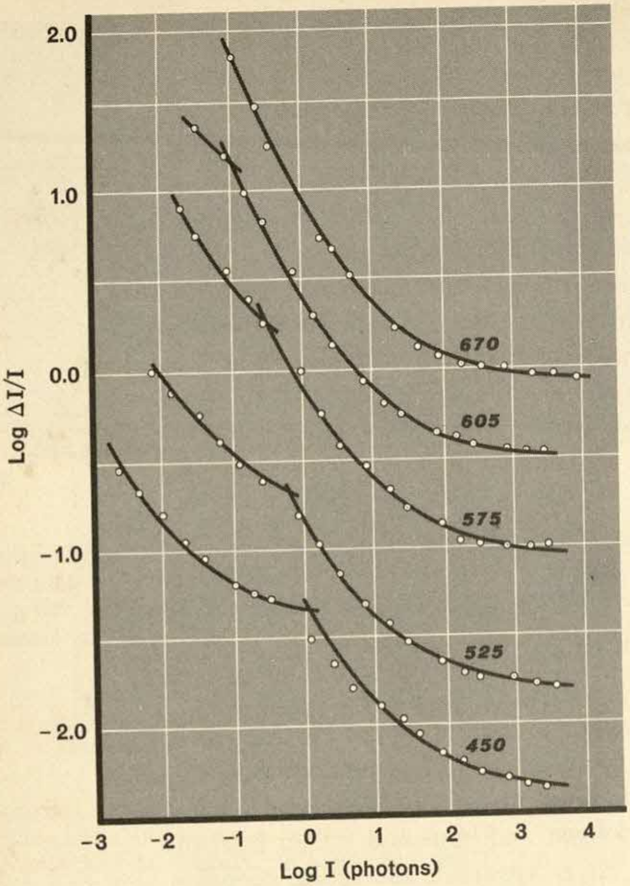


FIGURE 7.3. Discrimination of brightness at different intensities for wave lengths corresponding to red, orange, yellow, green, and blue. The labeling on the ordinate applies to the data for yellow (575 mμ). In order to compare the functions, the orange curve has been raised 0.5, the red 1.0 log unit; the green has been lowered 0.5, and the blue 1.0 log unit. (From Hecht, S., et al., Intensity discrimination in the human eye: II. The relation between ΔI/I and intensity for different parts of the spectrum, J. gen. Physiol., 1938, 22, 7-19)

required for discrimination at high levels is much smaller than that required at low levels of intensity.

One of the best methods of measuring the differential threshold is to provide a circular patch of light separated into two semicircles by a thin line down the middle. The illumination of the two semicircles is independently controlled. The individual is then asked to report which half of the field appears brighter, when the entire field is exposed for a brief interval. With a series of such exposures in which the differences (ΔI) between the two semicircles are systematically varied, it is possible to determine the value of ΔI which represents the threshold, that is, causes a discrimination to be made 50 percent of the time.

Visual Acuity

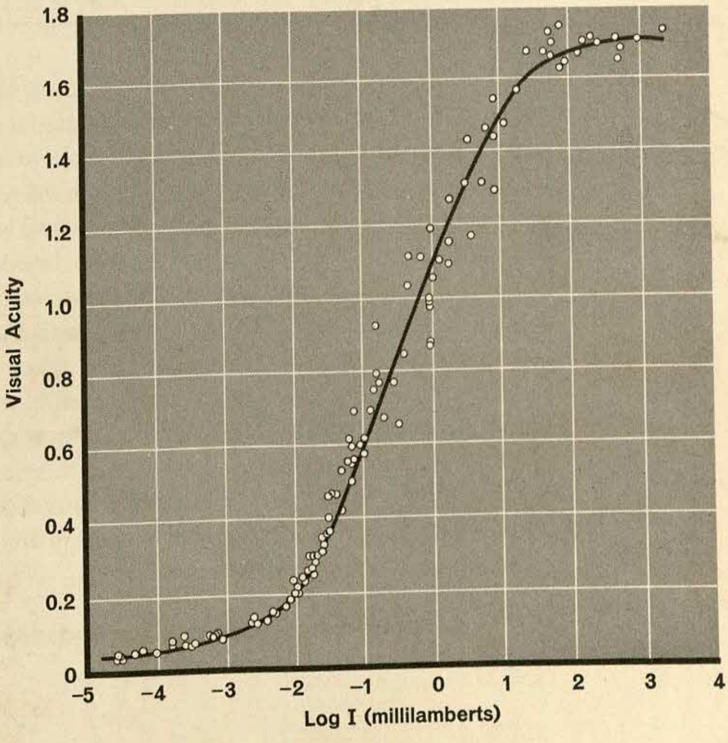
Another important visual discrimination is called *acuity*, the resolution of detail. In its fundamental meaning, acuity is the discrimination of two contours (black lines) separated by a minimum amount of illuminated (white) space. A familiar device used to measure acuity is the Snellen Chart, containing rows of printed letters of decreasing size. More precise measurements are obtained with broken circles and with gratings having standard dimensions.

Acuity varies greatly depending on the part of the retina stimulated. In general, the greatest acuity is achieved with the central retina, and there is a progressive falling off as one proceeds into the periphery. In everyday vision, we turn our head and eyes toward an object in order to focus the illumination on the central retina and thus to discriminate details. As is well known also, we are able to make such discriminations better as the surrounding illumination is increased; we can read fine print more easily in brighter than in dimmer light. This relationship between acuity and illumination is shown in Figure 7.4.

Color Discrimination

There are two kinds of visual discrimination which apply to the "color" of light. The first is *hue* discrimination, which is the distinguishing of one wave length of light from another. When we are able to discriminate one

FIGURE 7.4. *The relation between visual acuity and intensity of illumination. (From Hecht, S., The retinal processes concerned with visual acuity and color vision,* Bull. Howe Lab. Ophthal., *Harvard Medical School, 1931, No. 4, 1-88)*



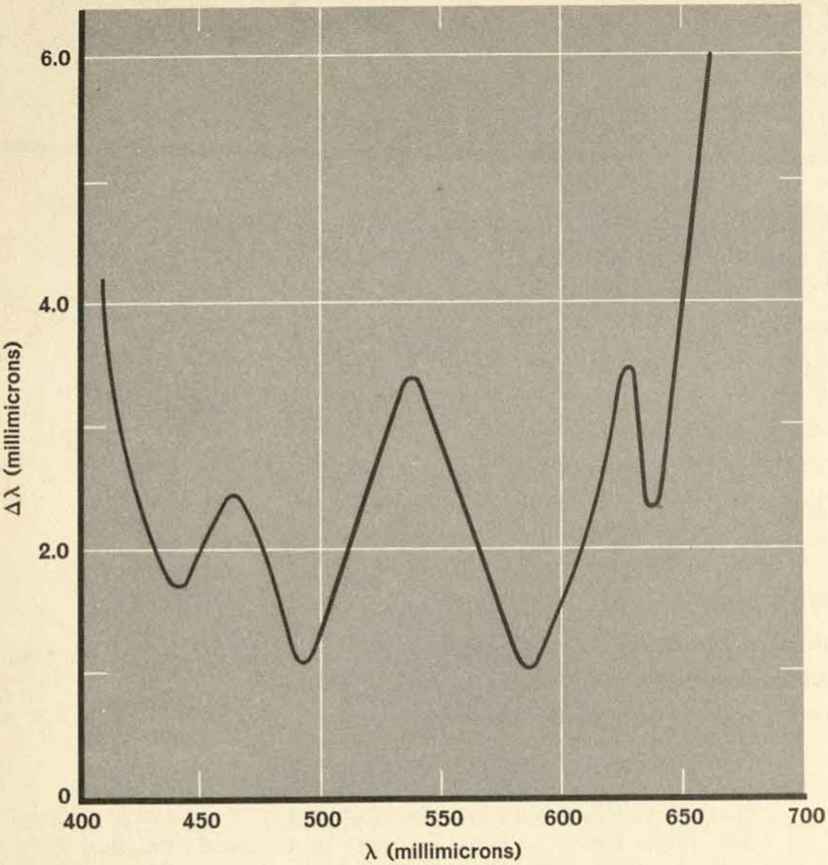


FIGURE 7.5. *The discrimination of wave length. The small change in wave length which makes a discriminable difference (Δλ) is plotted as a function of wave length (λ). (Data from Jones, L. A., The fundamental scale of pure hue and retinal sensibility to hue differences, J. opt. Soc. Amer., 1917, 1, 63-77)*

green as bluer than another, we are making a discrimination of hue. The second kind of discrimination we are able to make relates to degrees of *purity* or *saturation* within a single dominant wave length; one green may be highly saturated, another pale and washed out, because the latter contains other wave lengths (or white light) besides green. Saturation is not to be confused with intensity, as may be shown by the fact that two greens may be matched in brightness, but one may be a highly saturated "pure" green, whereas the other may be a "pale" green of low saturation.

Hue discrimination, the discrimination of wave lengths along the total visible spectrum, yields a complex function as shown in Figure 7.5. As the figure shows, the differences leading to discrimination (Δλ) are relatively small in the region of 490 mμ (blue-green) and 580 mμ (yellow). Relatively large changes in wave length are necessary for discrimination at both the violet and red ends of the spectrum.

Color-Blindness

Just as the discrimination of wave length seems a somewhat complex affair, so is the matter of color-blindness. Presumably the two functions share this quality because both are dependent primarily on the structure of the sensitive cells in the retina. A great deal of investigation has been carried out on color-blindness, in an attempt to determine what colors are confused in this condition. The evidence appears to support the idea that there are distinct types of color-blindness which produce qualitatively different kinds of color confusions, none of which occur in "normal" individuals.

Red-green blindness is the most common category of color-blindness, and occurs in 5 to 8 percent of the male population. It is transmitted as a sex-linked characteristic, so that the proportion of females who are red-green blind is relatively slight. Yellow-blue blindness is known to occur, although it is very rare. Rarer still is total color-blindness, in which the individual is unable to make any discriminations based on wave length.

DISCRIMINATION IN HEARING

Sound waves are generated by vibrating sources and transmitted

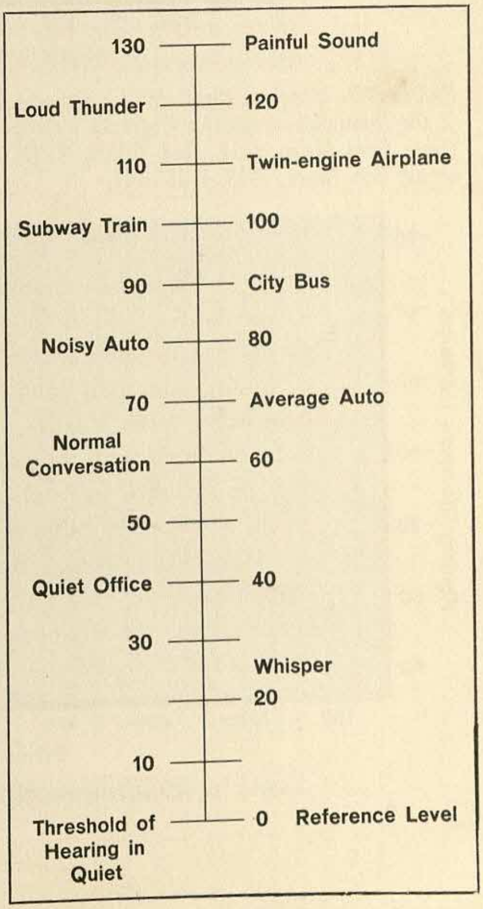


FIGURE 7.6. *The intensity of some common sounds expressed in terms of the decibel scale. (After Chapanis, A., Garner, W. R., and Morgan, C. T.,* Applied experimental psychology. *New York: Wiley, 1949)*

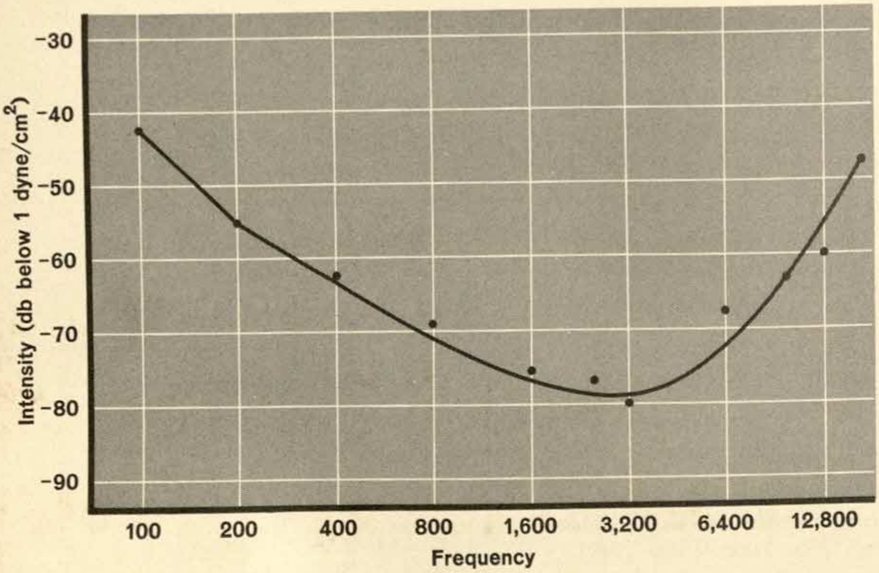
through the air (or other medium) as wave motion. The frequencies of such motion which can be heard range between 20 and 20,000 cycles per second. In other words, the wave length or vibration *frequency* of sound waves is one characteristic that can be discriminated. A second is the *intensity* of the sound, measured as the pressure exerted by a vibrating column of air, and usually expressed in terms of dynes per square centimeter (dynes/cm.^{2}). It is common to use a logarithmic scale to measure changes in sound intensity, just as it is for light intensity. The particular unit employed for sound is called the *decibel,* which relates to the ratio of two sound pressures in this way:

$$\text{No. of Decibels} = 20 \log p1/p2$$

The decibel scale of sound intensity is usually related to a standard reference value of 0.0002 dyne/cm^2. The relation of this scale to some common sounds is illustrated in Figure 7.6.

We learned in Chapter 2 that sound waves from the air pass into the external auditory canal and set the eardrum in motion. Attached to the eardrum are three small bones in the middle ear which carry the oscillations to the fluid of the cochlea through a membraned opening called the oval window. The fluid is set into motion, and stimulates the hair cells which are the hearing receptors. These set up the neural impulses which make

FIGURE 7.7. *Absolute thresholds for frequencies between 60 and 15,000 cps. Values of the thresholds represent averages for a group of young adults with "normal" hearing. (Data from Sivian, L. J., and White, S. D., On minimum audible sound fields, J. acoust. Soc. Amer., 1933, 4, 288-321)*



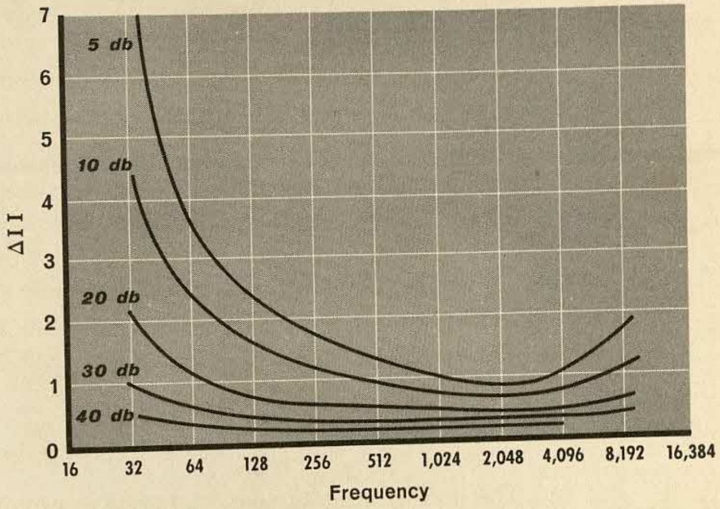


FIGURE 7.8. *Differential thresholds for intensity of sound waves. The seven curves shown were obtained by the "beat" method, with the standard tone set at 5, 10, 20, 30, 40, 60, and 80 db above absolute threshold for each frequency employed in the measurement. (After Riesz, R. R., Differential intensity sensitivity of the ear for pure tones, Phys. Rev., 1928, 31, 867-875)*

discrimination of sound possible. As we have seen, nerve connections originating in the auditory nerve terminate in the cerebral cortex.

Absolute Threshold

The minimum audible sound intensity for frequencies between 60 and 15,000 cycles per second is shown in Figure 7.7. Lowest intensities are required for the range of frequencies between 1,000 and 5,000 cycles. As in the case of vision, the human individual is most sensitive to frequencies of middle range.

Differential Threshold for Intensity

In contrast to visual discrimination, two tones differing in intensity (ΔI) cannot be discriminated when they are presented together to the same ear, for when this is done the loudness is simply added. Discrimination may be measured when the tones are presented successively, but this method introduces undesirable transient sounds. Another procedure is to present two tones which differ by 3 cycles per second (symbol: ~), thus producing "beats" of 3 per second, caused by the physical interference of the sound waves. The amount of added energy required in the second tone in order for beats to be heard gives a measure of ΔI. Data collected in this way are shown in Figure 7.8.

Differential sensitivity is greatest in the middle range of frequencies (2-5,000 ~), as is true also of absolute sensitivity. Although the curves of Figure 7.8 plot ΔI/I against frequency, an idea of the variation of this fraction can readily be gained by comparing the curves at increasing levels of intensity above threshold. At high intensities, such as 80 db, the value

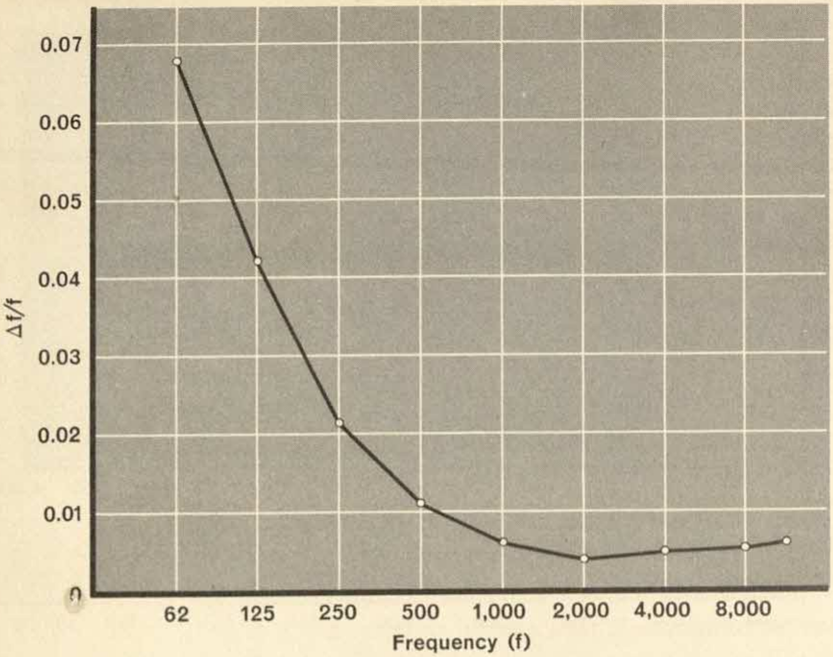


FIGURE 7.9. *Differential thresholds for the discrimination of frequencies, using tones at 10 db above absolute threshold. Tones were presented to subjects in pairs, and measurement was made of the minimum frequency reported as a "warble." Each threshold value is an average of 10 to 20 observations. (Data from Shower, E. G., and Biddulph, R., Differential pitch sensitivity of the ear, J. acoust. Soc. Amer., 1931, 3, 275-287)*

of the fraction is very small, and becomes much larger at low intensities. The size of a detectable difference in intensity is thus disproportionately small at higher intensities of sound.

Frequency Discrimination

In measuring discrimination of frequencies, two tones differing by Δf are presented simultaneously to the same ear. The differential threshold is that value of Δf which, on the average, makes a "warble" be heard, rather than a continuous tone. Results obtained using this method are shown in Figure 7.9. As can be seen, it takes a relatively large Δf to be discriminated at low frequencies. The size of this difference diminishes progressively, to about 800 cycles, and then remains roughly constant through 8,000 cycles. The discriminable difference rises again to some extent at higher frequencies. This general pattern occurs at both low- and high-intensity levels, although only one of these (10 db above absolute threshold) is shown in the figure.

THE LOUDNESS OF DIFFERENT FREQUENCIES. It is an interesting fact that two different frequencies can not only be discriminated in *pitch* (highness

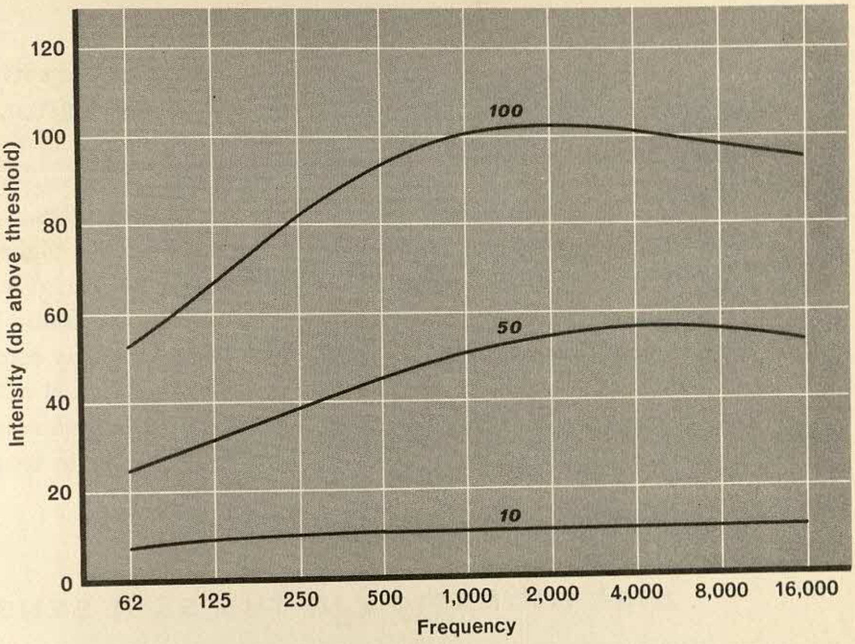


FIGURE 7.10. *The loudness of tones at different frequencies. The curves are called "loudness-level contours," and express the fact that all tones on each curve sound equally loud. The number above each curve identifies the number of db above absolute threshold used for the setting of the reference tone of 1,000 cps. Thus, at 10 db above threshold, changes in frequency alter loudness very little, whereas at 100 db, tones lower than 1,000∽ must be reduced considerably in order to sound equal in loudness to 1,000∽. (Adapted from Fletcher, H., and Munson, W. A., Loudness, its definition, measurement, and calculation, J. acoust. Soc. Amer., 1933, 5, 82-108)*

or lowness), but they can also be discriminated in *loudness.* In other words, two tones differing in frequency do not necessarily sound equally loud because they are at the same level of physical intensity. They may still be discriminable in loudness if the hearer is told to ignore the difference in pitch. This can be shown by asking an individual to discriminate the loudness of a tone from a reference tone of 1,000 cycles, and then adjusting the intensity of the second tone until it is not reported as different in loudness. Data which show the relationship between frequency and loudness are shown in Figure 7.10. These are called loudness-level contours. All tones on each curve *sound equally loud.* As can be seen, a 1,000-cycle tone of 100 db sounds equivalent in loudness to a 100-cycle tone of 60 db, and to a 30-cycle tone of 37 db.

OTHER AUDITORY DISCRIMINATIONS. There are a number of other types of auditory discrimination, dependent upon more complex circumstances than those we have described. When two tones are presented to the same ear, a number of effects can result, all of which depend fundamentally on the structure of the ear and the fact that it is by no means a perfect analyzer of complex sounds. *Beats* occur because of the interaction of two tones which differ slightly in frequency. There are also *difference tones*, heard as a pitch represented by the difference in frequency of the two tones, and *summation tones*. Some combinations of tones are *consonant*, and some *dissonant*, and it is generally thought that the explanation of these is to be found in the interferences (i.e., beats) between the higher harmonic overtones of the fundamentals, occurring within the ear. Finally, there is the phenomenon known as *masking*. If two tones of differing intensity and frequency are led to the same ear, the stronger tone may completely mask the weaker; that is, the weaker tone may not be heard at all. In general, the masking effect of a tone is greater the closer in frequency is the masked tone. Masking tends to be greater of tones higher in frequency (than the masking tone) and less for tones lower in frequency.

DISCRIMINATION IN THE SKIN SENSES

Pressure

Intensity of pressure stimulation is measured as tension, the amount of force per linear extent of skin surface contacted. In studies of pressure discrimination, the intensity is controlled by exerting known forces on fine stiff hairs or needles with measured radii. In one study of skin sensitivity, a graded series of forces applied in fine hairs was used to determine absolute threshold on a patch of skin on the back of the hand. As the intensity of stimulation increased from 0.01 to 1.60 gram, an increasing number of sensitive spots was found in an area of one square centimeter. At the highest intensity, a response to pressure was obtained wherever the stimulating hair was applied. These results are indicated in Figure 7.11.

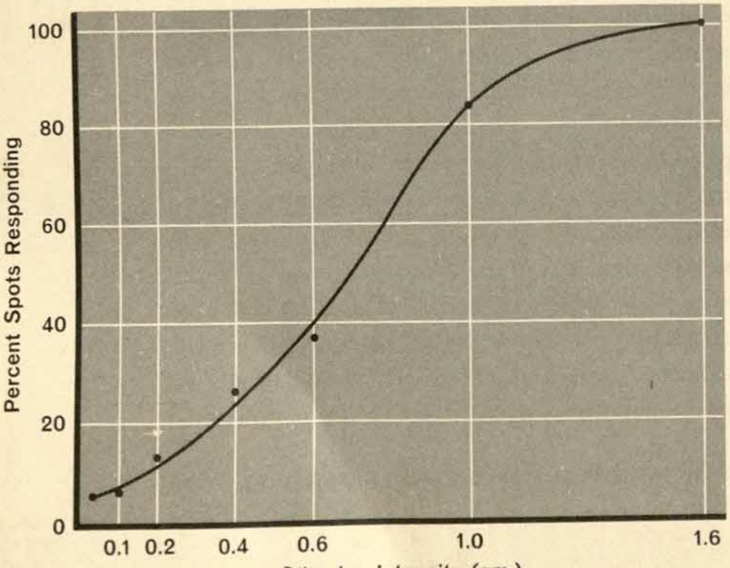


FIGURE 7.11. Absolute thresholds for pressure, determined by measuring the proportion of spots responding in an area of one square centimeter on the back of the hand. Intensity of the stimuli ranged from 0.01 to 1.60 gm. (Data from Guilford, J. P., and Lovewell, E. M., The touch spots and the intensity of the stimulus, J. gen. Psychol., 1936, 15, 149-159)

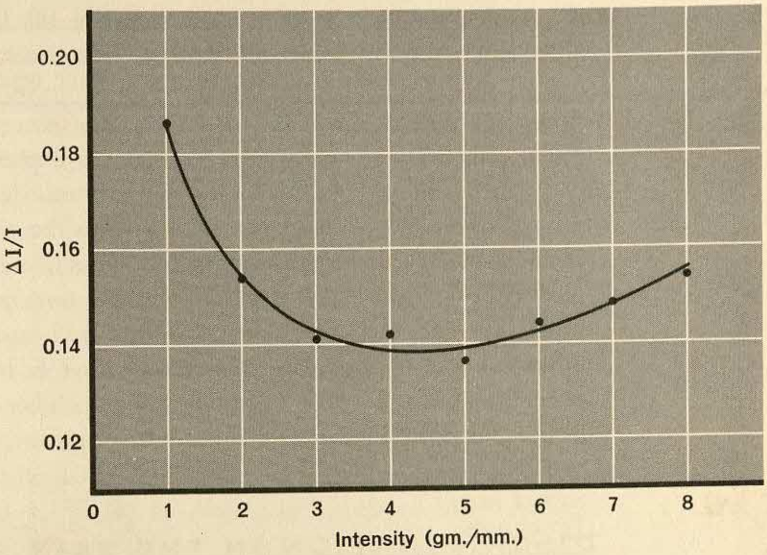


FIGURE 7.12. *Differential threshold for pressure, as a function of intensity, obtained for a single pressure spot. (Data from Gatti, A., and Dodge, R., Ueber die Unterschiedsempfindlichkeit bei der Reizung eines einzelnen isolierten Tastorgans,* Arch. ges. Psychol., *1929, 69, 405-425)*

The nature of the differential threshold for pressure is shown in Figure 7.12, as obtained for a single pressure spot. As with other senses, the proportionate increase in intensity ($\Delta I/I$) required to produce a differential response appears to be least in the middle range of intensities, and highest at the low end.

Pain

Many kinds of stimuli have been employed to measure thresholds for pain, including weighted needles, hairs, glass fibers, and heated surfaces such as tiny balls of solder cemented to needle tips. The evidence is that the absolute threshold for pain in a given skin area is reached at a given level of *pressure,* expressed usually in grams per square millimeter. In other words, the constant factor in pain-arousal is the lateral stretch of skin tissue. Presumably, it is this stretching of skin which makes a cut painful; when collodion is applied to immobilize the skin, the pain disappears.

Different parts of the skin surface show very different degrees of sensitivity to pain. In classical studies, the number of "spots" of the skin surface which will react to pain stimulation (sharp pointed hairs) have been mapped out on various body areas. These findings are given in Table 7.1. Some areas of the body are apparently quite insensitive to pain, if not com-

TABLE 7.1
PAIN SENSITIVITY OF DIFFERENT BODY SURFACES

SKIN REGION	PAIN "POINTS"/ CM²
Back of knee (popliteal fossa)	232
Neck region (jugular fossa)	228
Bend of elbow (cubital fossa)	224
Shoulder blade (interscapular region)	212
Volar side of forearm	203
Back of hand	188
Forehead	184
Buttocks	180
Eyelid	172
Scalp	144
Radial surface, middle finger	95
Ball of thumb	60
Sole of foot	48
Tip of nose	44

(Data from Geldard, F. A., *The human senses*. New York: Wiley, 1953. After H. Strughold.)

pletely so. The mucous lining of the cheeks and back parts of the mouth are relatively insensitive. Many of the internal organs of the body are insensitive to pain produced by surgical cutting. On the other hand, extreme sensitivity to pain is exhibited in some tissues, including the eardrum and the cornea of the eye.

Differential thresholds for pain have been measured by means of an apparatus which focuses the heat from a 1,000-watt lamp, varied in intensity by a rheostat, on a small area of the forehead.[1] With this method, the fraction $\Delta I/I$ has been found to remain relatively constant throughout the lower ranges of intensity, and then to increase progressively for the remainder of the measurable range. Actually, the entire range of intensities between detectable pain and the value which produces a skin burn is quite restricted; only 21 discriminable steps (ΔI) were found between these two intensities.

DISCRIMINATION BY OTHER SENSES

Few quantitative data can be found at present to describe the discriminations which are possible through stimulation of the senses of temperature, kinesthesis, smell, and taste. Obviously, human beings are capable of making such discriminations, but their exact measurement is complicated by lack of knowledge of the precise nature of the stimulus in each case, or by difficulties in applying the necessary stimulation in a way which excludes other variables. It will be sufficient to note here that the concepts of absolute threshold and differential threshold apply to the discrimination of stimuli in all of these senses. Furthermore, in each case (as is true also for other senses), discrimination is affected by physiological *adaptation* of the receptors. A given outside temperature "feels" colder when one goes outside from a warm room than when one emerges from a cold room. The second piece of candy tastes less sweet than the first, because the receptors for taste have undergone adaptation in the meantime.

While it is desirable, eventually, to have precise knowledge of the limits of discrimination in these other senses, such information will presumably be of limited practical usefulness. Vision and hearing are the most highly developed and useful senses in man, and most of his work is mediated by stimuli appropriate to these senses. The degree of handicap experienced by a blind man is of an entirely different order of magnitude than that of a man who cannot smell, or taste, or discriminate temperature changes. Man's relationship with his environment, including the tools he uses and the machines he operates, is dominated by and fundamentally dependent upon discriminations of light waves and sound waves. Discriminations of pressures, smells, tastes, and other forms of stimulation play a very subordinate part in everyday behavior, although they sometimes "support" the primary senses, as when a coarse-textured cloth is felt as well as seen.

IDENTIFICATION

As we have seen in Chapter 3, the discrimination function is only the first step in the organization of behavior. Although it is of basic importance that a human being *can* respond differentially to differences in stimulation, it is not always true that he *does* respond in such a simple way. Very often, the individual is concerned with *identifying* a light as *red*, as opposed to distinguishing one shade of red from another, or discriminating a small change in its intensity.

Seeing is a word which obviously has two meanings (as is true also of hearing, feeling, smelling, etc.). The first meaning is *sensing* or, as we have termed it, *discriminating*. But the more usual meaning is *perceiving*, or *identifying*. The sensing of the world is a very elementary kind of seeing. But we *perceive* the world as composed of colors, forms, locations in space, and objects with recognizable features.

How does the individual manage to identify colors, positions in space, shapes and forms, time intervals, melodies and harmonies? These are the types of activity which demonstrate the organized nature of behavior. They show also the dependence of behavior upon the existence of functional neural loops which develop as the individual interacts with his environment through the process of learning. The infant learns to identify colors, and sounds, and shapes, and many other aspects of his environment, by making identification responses which are reinforced when they are "correct" and suffer extinction when they are "wrong." By this means he acquires and stores what we have called *scales* and *models*, which provide functional connections between sensory neural impulses and the identification-responses that he uses. The process of refinement of these scales and models may go on for some time; it ceases when the environment no longer provides the necessary reinforcement for learning to occur. In the adult, we can often no longer demonstrate that scales and models are learned, since they are already there; but we can show that much additional refinement is possible through learning.

A famous American psychologist, William James, once said that the world must appear to the young infant as a "blooming, buzzing confusion."[2] By this he meant to imply, not that the infant cannot discriminate one light or sound from another, but that his world is essentially an environment which has not yet been organized into identifiable colors, shapes, and objects. Gradually the process of learning brings about the establishment of models and scales, so that a rainbow of red, orange, yellow, green, blue, and violet replaces a "blooming confusion," and reaching for a nearby face is not the same as reaching for the moon.

It is not easy to arrange an absolutely logic-tight demonstration that the world becomes organized for the individual because of learning through the reinforcement of identification responses, rather than through some innately determined neural organization. For example, it is difficult to arrange the proper experiments with young infants, particularly since they cannot make verbal responses, and because a well-controlled experiment of this sort would require some kinds of environmental controls which would be risky for human infants.

One experiment on innate vs. learned organization was done by raising an ape in total darkness from birth.[3] When finally brought into the light, we should expect that such an animal would be unable to identify shapes and spatial locations. This was found to be true; however, it was also noted that total darkness had apparently had some effect upon the normal growth of certain visual structures. Consequently, the results do not clearly prove the point. Many observations have been made on individuals blind from birth who have had their sight restored by surgery as adults. On the whole, the evidence supports the proposition that these individuals do not see an organized world when their sight is first restored. They must gradually acquire, through learning, the ability to identify colors, shapes, spatial locations, and distances.

Here we want to consider the nature of some scales and models that psychologists have studied over a period of many years. As we have said, these scales and models provide the individual with a world that is not simply a large collection of stimulus changes, but is organized into identifiable patterns. This organization must, of course, be based upon some orderly differences among the stimuli themselves; differences which are also discriminable. We shall describe first the identification of distance and depth, in terms of the kinds of scales on which it is based. There are a number of these, as we shall see. If for some reason one scale of depth is ineffective, the individual can fall back on any of a number of others.

IDENTIFICATION OF DISTANCE AND DEPTH

One of the ways in which the visual world is organized in a most interesting fashion is illustrated in our identification of spatial position. This activity is referred to as *distance perception*, or, when small physical distances are involved, as *depth perception*. We are able to identify the nearer and farther of two objects on a surface extending out in front of us. We can also identify the nearer and farther of two sides (or corners) of an object, thus making possible the perception of depth or three-dimensionality. What kind of models or scales enable us to do this?

First of all, we need to recognize that there is nothing inherently three-dimensional about the physical image which falls on the retina. Although the retina is curved, the kind of picture it receives is a two-dimensional image without any depth to it. If you look with one eye at two very thin black threads of indeterminate length, one physically more distant than the other, against the sky (or through a tube which blocks out all background) you will not be able to tell which is "farther" and which is "nearer." There is nothing *discriminable* in the retinal images of two such stimuli.

But looking at threads through a tube is obviously a rather special situation. Sometimes, the identification of distance is as undeterminable as this, as is true when we see an unknown aircraft (or flying saucer?) against the sky. But ordinarily, we do not look at things which are like thin threads, nor do we usually see things through a tube. In everyday observation, there are a great many cues to the perception of relative distance and depth. If distance and depth cannot be identified on the basis of the retinal image of the object itself, there are many other stimulus changes on which scales of distance (depth) can be based.

Accommodation

Kinesthetic stimuli associated with the use of the eyes are one basis for a scale of distance identification. When a single eye brings a near object into focus so that a sharp image falls on the retina, the ciliary muscles contract and make the lens assume a more rounded shape. When the eye brings a far object into focus, the lens is flattened by relaxation of these muscles. This mechanism of *accommodation* provides feedback kinesthetic signals (called "cues") which are the basis for a learned scale of distance. If the black threads of our previous example were replaced by rods of appreciable thickness (so that differential focusing were possible) and were placed, say, 5 to 15 inches from the eye, it would be perfectly possible to distinguish their relative position in space. If they were 20 and 25 feet from the eye, the kinesthetic cues from accommodation would probably not be discriminable. The degree of precision of the distance scale based on accommodation is probably not very high in most people. But because we have so many other scales, it does not need to be.

Convergence

A second distance scale based upon kinesthetic cues originates in *convergence,* a mechanism in which the two eyes act in concert. When both eyes together look at a near object, there is contraction in the muscles which turn the eyes inward (toward the nose) in their sockets, and simultaneous relaxation of the muscles on the outer sides of the eye sockets. When one looks at a far object, the opposite events occur in these muscles, and the eyes undergo *divergence.* Again, the kinesthetic signals provided by the convergence-divergence mechanism form the basis for a learned scale of distance discrimination. It is probably not very precise in most people, and it cannot extend beyond about sixty feet, since cues from it are no longer discriminable beyond that point.

Visual Background Cues

Many of the discriminations which make distance identification possible arise from parts of the total visual image (although, as we shall see, not necessarily from the object whose spatial position is being identified). We shall call these *visual background cues,* to distinguish them from the kinesthetic cues previously described. Some of them depend upon the use of the two eyes, and are therefore called *binocular cues;* most are present whether two or only one eye is employed and are called *monocular cues.*

BINOCULAR CUES. *Binocular parallax* is a general term used to describe the differences which may be discriminated in the images falling on the two eyes. Because the eyes are several inches apart, there is some lack of correspondence between the images which fall on each. If we have three black rods and are focusing on the middle one, as shown in Figure 7.13, the nearest rod will cast two disparate images on the two eyes, such that the left-hand image falls on the right eye and the right-hand image falls on the left eye. (The rule is, images of objects nearer than the fixation point are *doubled* and *reversed*). The farthest rod will also cast two images on the eyes, but in this case the right-hand image falls on the right eye, the left one on the left eye. (Images of objects farther than the fixation point are *doubled* and *not reversed*).

The disparity of images caused by binocular vision also plays a part in the perception of three-dimensionality. The same fact of image-doubling is true when one looks at a solid object. The right eye sees a little more of the right side of the object than does the left; the left eye sees more of the left side of the object than does the right. The images which fall on the two retinas are not exactly the same. Yet, instead of actually "seeing double," we see the object in three dimensions. There is a kind of fusion of these disparate images into a single perception of a solid object.

This principle is made use of in the *stereoscope*, a device which presents slightly different pictures, taken with two camera lenses separated at

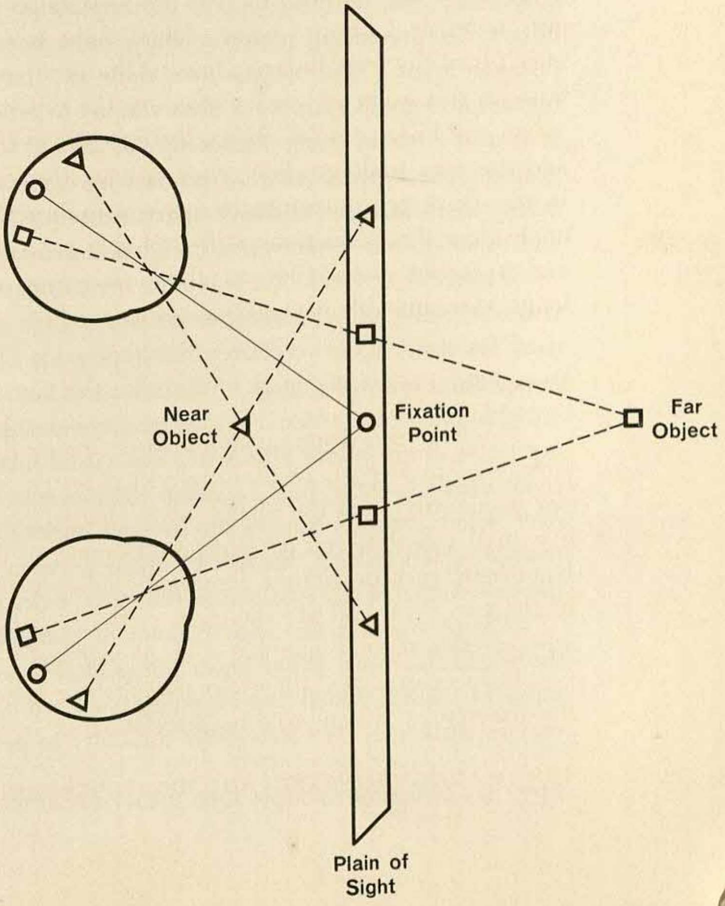


FIGURE 7.13. *The doubling of images in binocular parallax. The eyes are fixated on the small circle, and images of other objects are seen in this same plane of sight. As a result, images of a near object (small triangle) fall on different parts of the two retinas; the image is doubled and reversed, since the image to the left of the fixation point falls on the right eye, and vice versa. Images of a far object (small square), also fall on different parts of the two retinas, but this time they are unreversed.*

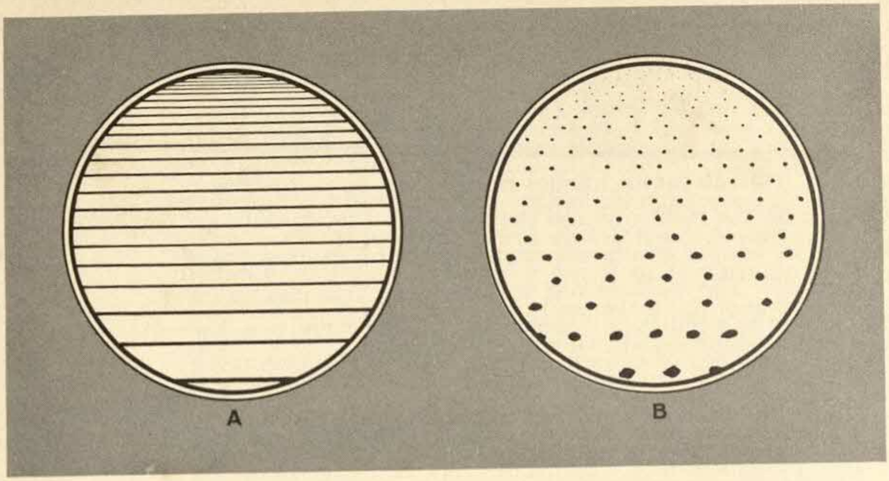


Figure 7.14. *Gradients of texture producing linear perspective. In A, the visual field of the eye is represented as a set of parallel lines of decreasing separation. B illustrates how a texture of dots of decreasing size and separation conveys the impression of depth through linear perspective. (Adapted from Gibson, J. J.,* The perception of the visual world. *Boston: Houghton Mifflin, 1950)*

the same distance as the two eyes, one to each eye. These images fuse into a single perception of a scene or object with three dimensions. The stereoscope may also be used to give the impression of unusual distorted depth effects, by presenting pictures which have been taken at more than eye-distance apart. This is sometimes done in "stereoscopic" movies (employing red and green glasses for observation) in order to create unusual effects. It is also done in using stereoscopy as an aid in interpreting aerial photographs. These photographs are taken by cameras whose lenses are considerably more than eye-distance apart; consequently, the solidity of buildings and other objects when seen through a stereoscope is quite startling.

Monocular Cues. Probably the most important monocular cue is what is traditionally called *linear perspective,* which artists have recognized and used for many years to convey the impression of depth in pictures. Linear perspective is a term used to describe the fact that the total set of differentiable parts of the visual field of one eye shrinks progressively to a vanishing point at an infinite distance. The visual images of objects get progressively smaller as the field of vision extends into the distance. The surfaces over which we look toward the horizon impose on the retina a *gradient of texture* which reflects this fact of linear perspective. Figure 7.14 illustrates the occurrence of this gradient in the visual field of one eye.

Unless we take the special point of view of the artist, we do not see the world this way. What linear perspective provides us with is an ordered series of stimuli which can become associated with responses that identify various distances. We have little difficulty in perceiving railroad tracks receding into the distance; that is, in identifying successive points along the track as being more and more distant. This is because of the fact that the images of spaces between ties and between rails grow closer and closer together as the horizon point is reached. The identifying responses to these images are those of increasing *distances,* rather than of progressive narrowing of the tracks. In other words, we respond to the tracks as *actually* receding into the distance. (This is not to deny that we can, if called upon, take the point of view of the artist, and make a drawing which represents the linear perspective of the field of view).

OTHER VISUAL BACKGROUND FACTORS. Although tremendously important, linear perspective is not the only source of stimulation which makes possible the identification of distances. Another kind of ordered stimulation (or gradient) is found in *aerial perspective,* which is the name given to the progressive haziness of outline of objects as their distance from the eye increases. There are also gradients caused by *shadows,* which depend upon the fact that light coming from above produces a progressive shading on a convex surface which is exactly the reverse of that produced on a concave surface. For this reason, if an observer looks at a photograph of the moon's surface turned upside down, he tends to see the craters as hills. Finally a kind of all-or-none order of stimulation (as opposed to a gradient) is provided by the *interposition of objects.* When the visual field contains a house whose outline is partly blocked by a tree, this forms the basis for identifying the distance of the house as greater than that of the tree.

The Nature of Identifying Responses for Distance

People vary a great deal in their ability to make accurate responses to distance. One person may have acquired a "foot" scale which turns out to be quite accurate when we ask him to identify absolute distances along the ground; another person's "foot" scale may have a considerably lower degree of precision. So far as the perception of distance is concerned, these absolute distances are of course quite arbitrary. We in the United States use "yards," and learn absolute scales in terms of this unit, whereas other people use "meters." We can learn new scales of this absolute sort quite readily; watching football soon gives us a scale of five-yard units.

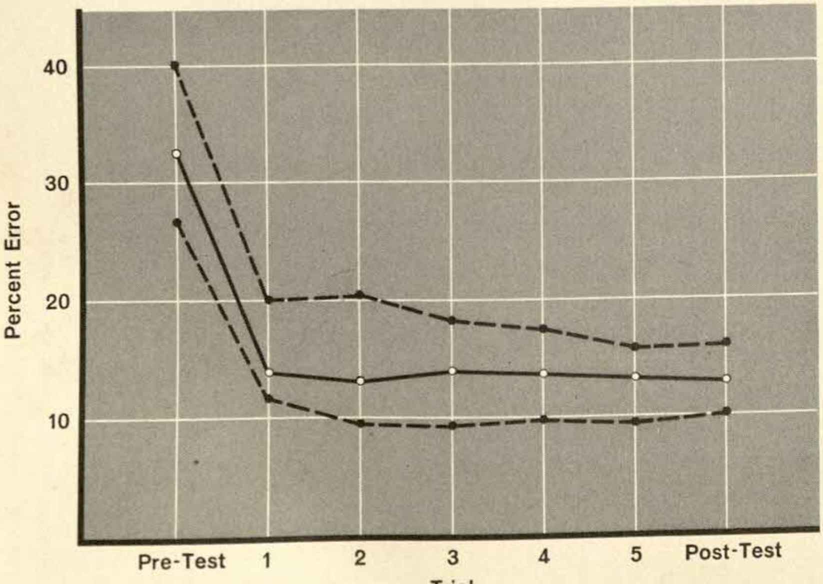
The basic kind of distance scale which we all acquire, however, is probably not one of this absolute sort. It seems rather to be a relative scale whose units may be any of a variety of standards previously encountered by the individual. This makes it possible for us to identify distances in a relative sense regardless of the specific absolute physical units employed. Suppose, for example, we ask two individuals to estimate the distance away in feet of objects which actually stand 100 feet from the point of observation. One person may estimate 97 feet on the average, the other 60 feet. This is an indication that the units of the first individual's "foot scale" have greater precision than do those of the second individual.

But does this mean that the two individuals differ in their ability to perceive distance? Not necessarily. It may simply mean that the identification of the arbitrary unit "one foot" is better in one case than another. Suppose now we present each of these observers with a plain unmarked stick twenty-one inches long. We do not tell them its length in inches. We simply ask each to estimate how many "stick-lengths" distant are the objects concerned. Under such circumstances, we shall find differences between these individuals, no doubt, but they will probably be quite small in relation to the differences in precision of their "foot-scales." Their ability to identify points along the ground each of which is farther away than the last, in terms of arbitrarily defined stick-lengths, may be quite comparable.

The Learning of Distance Identification

An interesting study was done to determine whether individuals can improve their identification of distances in terms of absolute measures. In this case identifications were required in yards. The individuals in this experiment observed "targets" placed at various distances ranging from 39 to 435 yards from the points of observation in an open field, and were asked

FIGURE 7.15. *Course of learning in a study of distance identification in absolute units (yards). The percent error is shown for a pre-test of 18 identifications, 5 training trials of 18 identifications each, and a post-test of 18 identifications. The values of the solid line are for crude median error; dotted lines enclose the range of error for 50 percent of the group tested. (After Gibson, E. J., and Bergman, R., The effect of training on absolute estimation of distances over the ground, J. exp. Psychol., 1954, 48, 473-482)*



to identify the distance of each target. Both the observation points and the targets' distances were varied in a number of practice trials, so that identification in terms of a particular target was impossible. After each identification, the individual was told the correct distance. Figure 7.15 shows the improvement made in these identifications during a "pre-test" (18 different judgments), 5 practice trials of 18 different judgments each, and a "post-test" of 18 judgments. The percent of error diminished markedly between the pretest trials and the learning trials, and little thereafter. Note that this was *not* a matter of learning the appearance of a particular strip of ground; rather, distance was identified in yards over a different stretch of ground in each judgment. The study shows, therefore, that the "yard scale" possessed by most untrained individuals can be rapidly and quite markedly improved by training in identification of distances of 40-400 yards in an open field.

The scale acquired by these individuals was shown to be one which exhibited a one-to-one relationship between perceived distance and actual distance. That is, within the range of 40 to 400 yards, there was no consistent tendency for over- or underestimation of near or far distances. While this is by no means true of all acquired scales, this one turned out to be linear.

The Distance-Size Relationship

As we saw when considering linear perspective, the images of objects grow smaller and smaller as the vanishing point is approached in the visual field. The correct identifying response to two objects of known size (such as men) which are of different size in the *visual image* (that is, on the retina) is therefore one of different distances; we see one as *farther away* than the other. However, the situation may be reversed. The visual background cues (gradient of ground texture) may indicate two objects of unknown size to be different distances away. Suppose, though, that their visual images are equal in size. In this instance the correct identifying response would be that one object is *larger* than the other. This second situation is illustrated in Figure 7.16.

Only under certain special conditions do we actually separate our responses of relative size and relative distance. They are actually interdependent in the perception of distance. Under ordinary circumstances we perceive, not size by itself or distance by itself, but size-at-a-distance. The phrase *size constancy* is used to express the fact that the size of an object receding into the distance is reacted to in a constant way (identified as the same size) despite the fact that the size of the visual image decreases because of linear perspective. Presumably, the factor that enables us to do

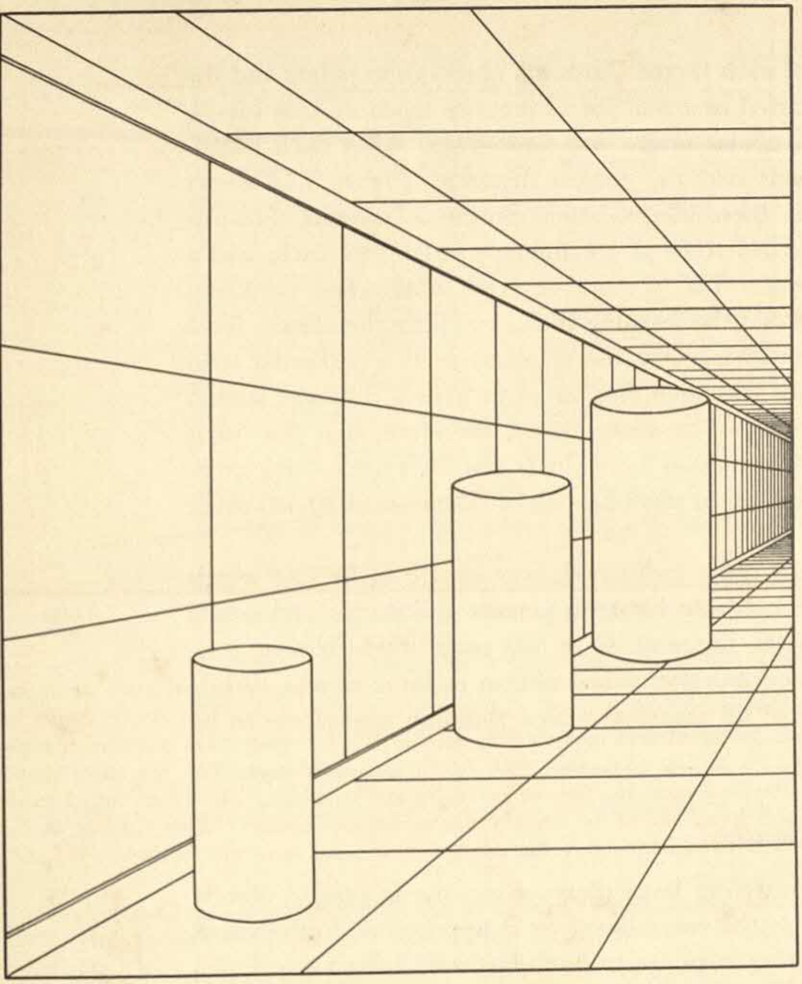


FIGURE 7.16. *Size identification as determined by visual background cues. The cylinders of the figure produce visual images of equal size on the retina. Because of the texture-gradient cues, however, they are identified as being different in size.* (From Gibson, J. J., The perception of the visual world. Boston: Houghton Mifflin, 1950)

this is our prior acquisition of a scale of distance. The stimulus conditions on which identification of distances are based are essentially the same as those which underlie the identification of size at different distances.

How good is our ability at identifying size-at-a-distance? Observers were asked to match triangles of unknown size placed at distances up to 4,000 feet away, with a comparison triangle (variable in size) 100 feet away. They behaved as shown in Figure 7.17 when instructed to make "objective" matches; that is, to identify the actual size of each triangle. Their identification of true size out to a distance of 4,000 feet was quite good, although the triangles at farther distances tended to be perceived as larger

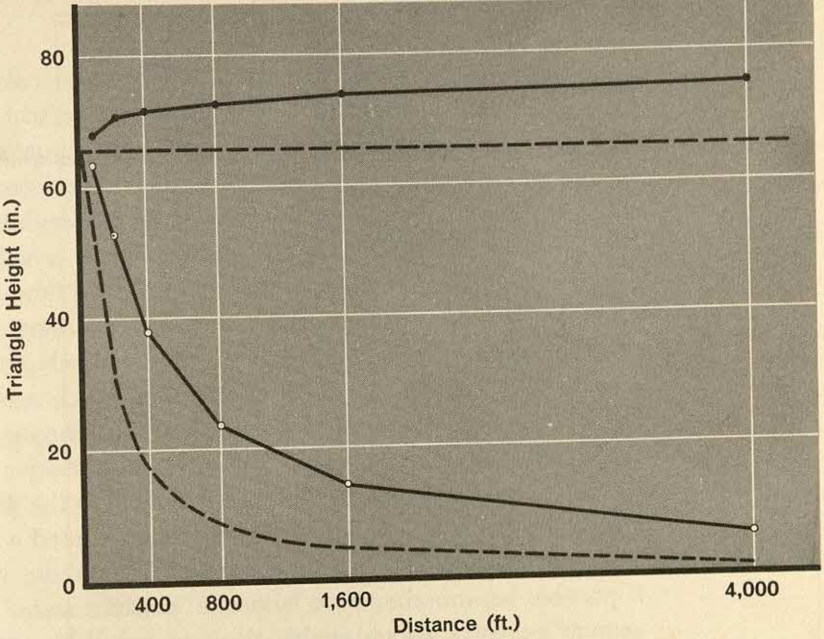


FIGURE 7.17. *The identification of real sizes of triangles at unknown distances. This figure shows the matches made to a standard equilateral triangle (66 inches in altitude) by adjustment of a variable triangle 100 feet away. The standard triangle was placed at 100, 200, 400, 800, 1,600, and 4,000 feet. The top curve shows "objective" matches, the bottom curve "retinal" matches. The lower dotted curve represents actual size of the retinal image at various distances. (After Gilinsky, A. S., The effect of attitude upon the perception of size,* Amer. J. Psychol., *1955, 68, 173-192)*

than their true size by about 20 percent in height. This is not very great, when one considers that the variation in height of the visual image, when an object is shifted from the distance of 100 feet to that of 4,000 feet from the observer, is 40 times.

Figure 7.17 also shows that people are able to identify the size of the visual image quite well, as indicated by the results shown in "retinal" matches. Again, there is a tendency for these to be identified as larger than they actually are, when greater distances are involved. This is, of course, an entirely different scale, and should not be confused with the one which expresses size-at-a-distance. When we identify the real size of objects at a distance, that is one thing. When we say "Objects grow smaller in the distance," we are speaking of the size of the visual image, and that is quite another thing. Human beings possess both types of scales. We can respond appropriately to real size and real distance. Alternatively, if we are drawing a picture in perspective, we can identify the size of the visual image.

IDENTIFYING DISTANCE AND CONCEPTUALIZING DISTANCE. One more fact needs to be mentioned here—the distinction between distance *identification* as given to us by acquired scales, and distance *calculation* based upon concepts. It is apparent from what we have said that human beings have an immediate appreciation of distance based upon acquired scales. Although such distance perception is not perfectly accurate, it is quite adequate for most purposes such as driving an automobile or landing a small airplane. But human beings also have concepts which apply to distance, capable of greater accuracy, which require more time for application. For example, there are geometrical concepts such as triangulation, which enable us to calculate the size of a distant object to a much greater degree of accuracy than is possible by direct observation. Such concepts are employed when accurate measurement is required, as in surveying a piece of property. We should not make the mistake, however, of assuming that a man's ability to use concepts to calculate distance is related to the way he perceives distance. We know that children who are unacquainted with geometrical concepts nevertheless identify distances and sizes quite well. This behavior is possible because they have learned a "distance scale." Later on, they will acquire concepts which enable them to calculate distances with greater accuracy. But an immediate appreciation of distance will always be possible, and so far as we know will not be influenced by this "higher level" ability.

OTHER VISUAL IDENTIFICATIONS

There are many other kinds of models and scales besides distance. Assuming that the visual world is initially a "blooming confusion," it is apparent that the individual must acquire and store a large number of models and scales which enable him to identify such things as numerousness, separateness, shapes, and the essential character of objects. After all, it is an organized visual world of numbers, spaces, shapes, and objects to which the adult human being reacts, not a world of gradations in intensity and wave length. What kind of organization does this world have?

Numerousness

A scale of numerousness is basic to our perception of the world, as well as to mathematical computation. We are able not only to discriminate the presence or absence of stimulation (the absolute threshold), and the separation between one stimulus and a second (the threshold of visual acuity), but we are able to identify "oneness," "twoness," and so on, regardless of the particular objects or stimuli which may be presented in ones or twos or threes.

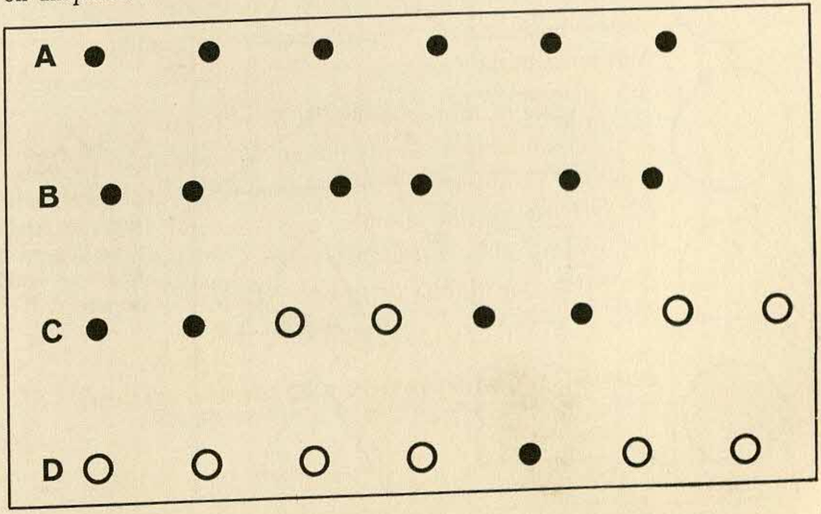
What kind of scale of numerousness do we have, and how extensive is it? This is a question which has intrigued many people. Originally, this question was answered by having a person identify, in a single glance, the number of beans which landed on a white tray when a lot of beans were tossed on a larger surface. A number of more elaborate methods have since been devised, generally involving the brief exposure of dots on a screen for a fraction of a second. The brief exposure is used to prevent counting, (which is, of course, a different method of identifying involving the use of number concepts). On the average, the number of dots which can be correctly identified without counting is six, and this number has been obtained in several different experiments on "span of apprehension." In other words, human ability to identify "oneness" and "twoness" apparently extends to "sixness" and no further.

Groups

When dots are presented in a random pattern for a brief exposure, the identification of more than six is unlikely. (Of course, six is the "threshold," and represents an average value; it would be incorrect to assume that an individual can *never* identify numerousness of more than six). But if it is possible for the observer to see the dots in groups, the number identified correctly is somewhat higher. Then, if the dots are deliberately arranged in groups, the identification of numerousness may be possible for much higher numbers of dots.

What makes it possible to identify groups as groups, rather than as individual objects? This ability apparently depends upon certain previously acquired models of spatial arrangement. Furthermore, the models which people have of groups appear to possess a universal quality, at least in their

FIGURE 7.18. *Some basic models of grouping. Line A illustrates no particular model of grouping; line B shows a model based on proximity; line C on similarity; line D on uniqueness.*



basic characteristics. In other words, these models appear to be determined by some innate qualities of the nervous system, because it is difficult for the human individual to acquire models of groups which are not structured according to these principles. Figure 7.18 illustrates some of these basic models. Line A contains dots which are not grouped into any particular configuration. Line B, however, tends to be identified as three groups, as determined by the *proximity* of the dots. Line C is identified as four groups, determined by *similarity* of the units. In line D, the *uniqueness* of the dot in the line of circles leads to the identification of two separate groups.

Shapes

Just as there seem to be some basic models of grouping, there are also undoubtedly some basic models for shape. These models, too, are probably inevitably learned. They depend for the existence not upon the accidental arrangement of the environment, but upon some basic principles of neural functioning. This appears to be the only way we can explain the universality of such models as the circle, the square, and the equilateral triangle. Many specific shapes are identified as variations on one or the other of these basic models. Figure 7.19 illustrates these shapes and some variations on them. Note that, regardless of the differences in specific shapes, there is little tendency to confusion between a circular shape, a "squarish" shape, and a triangular shape.

Besides these universal models of shape, the individual acquires many other specific models which are indeed the result of his own individual experience in his own environment and culture. When individuals are asked to make a number of successive reproductions of a "nonsense" figure, it is found that these drawings tend progressively to look like some common object. The parts of the nonsense figure which do not conform to the out-

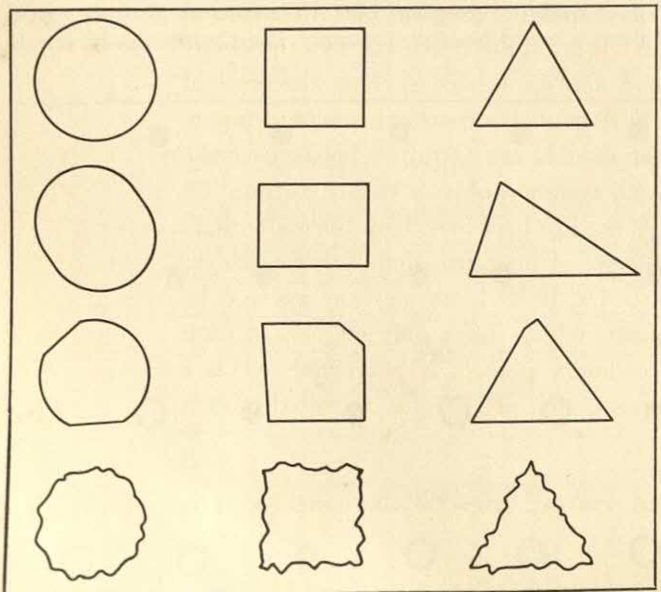


FIGURE 7.19. *Some basic shape models, and variations of them. Despite considerable variation in physical dimensions, we tend to identify each of these figures in terms of the model in the first row—circular, squarish, and triangular.*

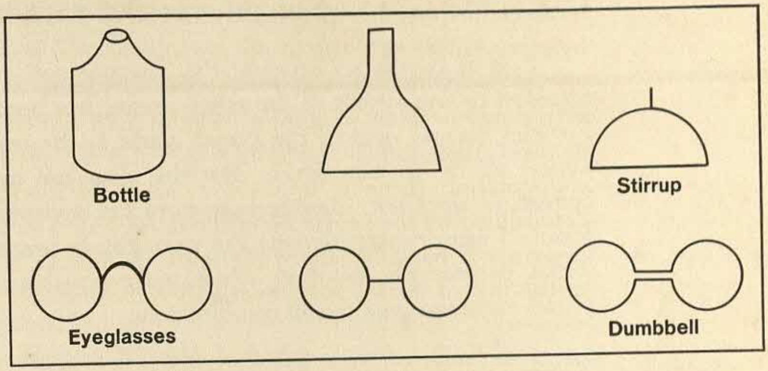


FIGURE 7.20. *Reproductions of nonsense figures which were said to resemble certain common objects. Although the individuals in this study were instructed to make accurate reproductions of the figures in the center, their drawings tended to resemble the models named. (After Carmichael, L., Hogan, H. F., and Walter, A. A., An experimental study of the effect of language on the reproduction of visually perceived form,* J. exp. Psychol., *1932, 15, 73-86)*

line of such an object tend to drop out; others tend to be distorted or emphasized in the direction of the model (the ordinary object). When the model is suggested to the individual before he draws, the tendency is even more marked to make the drawn figure like the model, rather than like the original nonsense shape. For example, Figure 7.20 shows what happened with successive drawings of two different nonsense figures shown in the middle column. When the top nonsense figure was said to resemble a bottle, the figure tended to be drawn like the one on the left; when it was said to resemble a stirrup, the tendency was to draw it as on the right. This was true even though the individuals were working under instructions calling for accurate reproduction.

In summary, the identification of shapes is based on certain acquired and stored models. Some of these models are quite universal, like the circle, square, and equilateral triangle (there may be others, such as the straight line and the spiral). These appear to depend for their existence on innate factors of neural organization. Other models are acquired because of the individual's particular experiences with common objects of his culture. Of course, particular sets of models may readily be learned by the individual. For example, he may acquire a whole set of nonsense shapes as models, as in the study described in Chapter 6. Or, if he is an airplane spotter, he must learn a set of models of airplanes which differ only slightly in their shapes. The visual world, for the ordinary person, is perceived not as a shapeless chaos, but as a set of shapes which are like his acquired models with variations.

IDENTIFICATION IN THE OTHER SENSES

It is of course no accident that the perception of the visual world, as opposed to the worlds of the other senses, has been so extensively studied. For the normal person, the visual world is the one that clearly embraces almost all of his experience. But this does not mean that the individual cannot, or does not, identify aspects of his environment by means of other forms of sensory stimulation. For example, in hearing we have models and scales, presumably acquired, which make possible certain identifications of sound variations and sound combinations.

Auditory Space Perception

Even though the source may be hidden, we are able to identify, with a fair degree of accuracy, the direction of sound which comes to us through the air. The scale which makes these identifications possible depends upon the different spatial locations of our two ears. There is a difference in *time* of onset and termination of a sound (such as a click), when the sound-source is located nearer to one side of the head than it is to the other. There is also a difference in *intensity* and (in the case of a continuous sound) in *phase* of the sound wave. All of these types of physical difference probably enter into the identification of a sound's location. It is easy to understand, then, that confusions in location at the left and right side of the head would be rare, since the stimulation of right and left ears is most distinctive in these instances. On the other hand, confusions between locations of sound at the front and back of the head are much more common, because differences between the sound at the two ears in time, phase, or intensity are absent in both cases. Generally speaking, there is considerable accuracy in identifying the angular deviation of a sound's location from the median plane of the head (direct front or back). Accuracy of identification in terms of angular deviation from the left-right plane is less. The order of magnitude of accuracy is about 3 degrees for the median plane, 9 degrees for the plane passing through the ears, and an intermediate accuracy for intermediate locations.

Avoidance of Obstacles by the Blind

It has been long known that blind people are able to find their way about a house, or a city, without bumping into things very often. They do this a great deal better than would a normal person with a blindfold. How is this possible? What kind of scale have blind people acquired which enables them to identify openings and obstacles?

There have been many theories about how this is done. Blind people themselves sometimes hold the theory that their faces are sensitive to waves emanating from surfaces, or to variations in air pressure produced by their approach to such obstacles ("facial vision"). Others tend to believe that auditory cues are involved. A series of experiments has been carried out to find the answer to this question.[4]

The hands and faces of blind individuals were covered with heavy material, so that changes in pressure reflected from a wall could not be detected. Under these conditions, the blind people experienced no difficulties in stopping before they bumped into a wall. In a second part of the experiment, their ears were plugged, but the material covering their faces and hands was removed. When this was done, they collided with the wall each time they approached it. A further test of the importance of auditory cues was then made. The blind individuals were placed in a soundproof room, with a pair of earphones on their heads. The earphones were connected to a portable microphone which was "walked" toward a wall by the experimenter. Again it was found that the blind people were able to indicate, with considerable accuracy, when the microphone was approaching the wall. There is little doubt, then, that the avoidance of obstacles by the blind depends on their hearing of sound waves reflected from surfaces.

Here, then, is an auditory scale which is of great importance to blind people, although not ordinarily possessed by non-blind people. It can be acquired by blindfolded people, when they set out to learn to avoid obstacles this way. However, it would probably take many months of practice for a normal person to acquire a scale having the precision of the one a blind person has.

Music

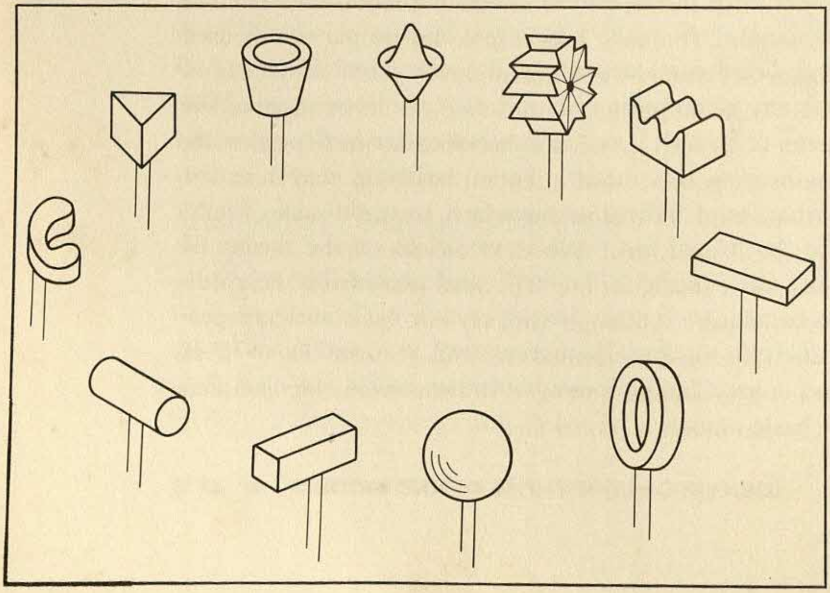
As we listen to and learn to respond to music, we acquire many kinds of models and scales, ranging from the basic scale and simple chords used in popular music, to the complex harmonies and contrapuntal structures of symphonic music. For any given piece of music, once we have acquired the basic model (the theme or melody), our enjoyment comes to depend more and more upon variations on this model. These variations may take the form of *ad lib* performances of individual musicians, as in the case of jazz, or they may be more the formal but intricate variations on the themes of classical music. In any case, music is "known" (and presumably enjoyed) because we are able to acquire models having certain basic auditory patterning, and thus to identify the basic pattern as well as variations of it. If we want to know and enjoy Chinese music, or Indian music, we need first to acquire some new basic models.

Other Scales and Models

It is doubtful that we have a good appreciation at the present time of the possible scales and models which may be acquired in relation to touch, smell, taste, and kinesthesis. We do not ordinarily have much need to make such identifications, and we therefore do not learn the models. Of course, there are special occupations which may require them. For example, those who inspect fabrics may need to acquire models of texture which enable them to do their jobs efficiently. Tea tasters and wine tasters have certainly acquired some unique scales, as have the "noses" who identify perfumes and their components.

When a complex job such as that of an airplane pilot requires continuous attention to visual and auditory cues, a tactual model may come in handy. For example, the pilot may have to operate a number of controls while watching the ground and his instrument panel, and listening to control-tower instructions over head phones. Under such circumstances, it may be desirable to provide him with control knobs which are highly distinctive in shape, so that the tendency to confuse one knob with another is reduced. If tactual models are to be used to aid his identification of controls, obviously knobs should be chosen which are most readily distinguishable. That is to say, previous identification learning with a great variety of shapes should make possible the identification of certain knobs with minimum error. A study was made of 22 knob shapes, chosen to be distinctive, in order to determine the number of times each one was confused when paired with each other one. Forty Army Air Force pilots participated in

FIGURE 7.21. *Eleven knob shapes which were identified without error from a group of 22 shapes. (After Jenkins, W. O., The tactual discrimination of shapes for coding aircraft-type controls. Ch. 14 in* Psychological research on equipment design *(P. M. Fitts, Ed.). Washington, D.C.: U. S. Govt. Printing Office, 1947)*



this study. They were blindfolded, and were then asked to identify a given knob, after feeling it for one second, out of a total set of 22. Eight knobs were found which were not confused at all with other knobs. A second study added three more knob shapes to this distinctive set. The eleven models are shown in Figure 7.21.

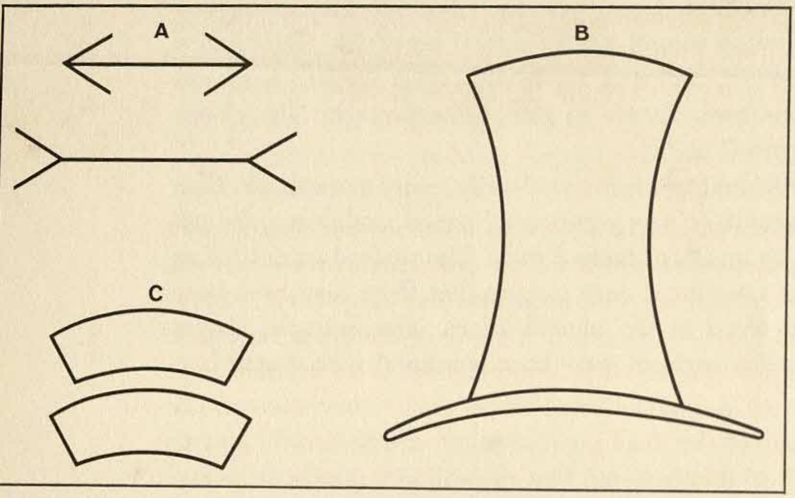
Presumably, an individual can learn to identify many more shapes than this. But here is an example of how previously learned models may be put to use in identification by means of tactual cues. The study does not tell us exactly what these cues are, but it does suggest that there may have been "families" of shapes involved in the identifications. For example, shapes with corners, edges and flat surfaces were never confused with shapes having rounded surfaces.

FACTORS INFLUENCING SCALES AND MODELS

Do the internally organized scales and models give an accurate picture of the outside world? For most purposes, they do indeed. We perceive distance with an accuracy quite good enough for most purposes of walking or driving or kicking footballs, despite a slight tendency to overestimate the sizes of objects that are far away. We seldom confuse a three-dimensional object with a flat surface; we identify colors rather well, whether they appear in shade or in sunlight; we locate the sources of sounds with little difficulty; and we recognize melodies with relatively little confusion.

Yet there are limitations to the accuracy of our learned models and scales, and there are also exceptional circumstances in which they do not function effectively. If we want to parcel an acre of land, we do not trust our distance scales, nor even those of a highly trained person. Instead, we reduce the problem to one of physical measurement, using a measuring tape. For the individual, this means that we replace direct distance identification with discrimination. This may take a little longer, but it results in greatly increased accuracy of distance determination.

Psychologists have been interested in studying a number of situations in which there is a lack of correspondence between acquired scales and objective measurements. A good deal of attention has been paid in experimental studies to various kinds of *distortions* which acquired scales exhibit as compared with physical measures. We shall consider here two of the most important factors in scale-distortion. The first arises from the nature of the stimulus-situation itself. Although we may not be able to identify the variables precisely, they may be termed *stimulus factors*. Their effects are shown in *illusions*. The second sort of distortion-producing influence on scales and models is that of *motivational factors*.



IGURE 7.22. *Some well-known illusions of length and size. A is called the üller-Lyer illusion, after two of its early investigators. The horizontal line etween inward-pointing arrows is identified as the shorter of the two. B is the ertical-horizontal illusion, in which the vertical length of the hat is identified as onger than the horizontal length. In C, the lower figure appears larger than the pper one.*

Stimulus Factors in Scale Distortion

Some well-known illusions pertaining to identifications of length and size are shown in Figure 7.22. In each of these, identifications are distorted by stimulus factors of one sort or another. In the Müller-Lyer illusion the scale we apply to the line between diverging arrows is different from the one we apply to the line between converging arrows. The lengths of two lines are accordingly identified as being different, whereas they are actually the same length physically. Similarly, our scale for vertical length differs from our scale of horizontal length in such figures as the tall hat, and the vertical-horizontal illusion is the result. This can be equally well demonstrated with a simple figure in which a vertical line bisects a horizontal line of equal length. In the case of the figures labelled C, we probably tend to apply the scale of length for the lower arc of the top figure to the upper arc of the bottom figure, and thus are "misled" to identify the lower figure as larger in area.

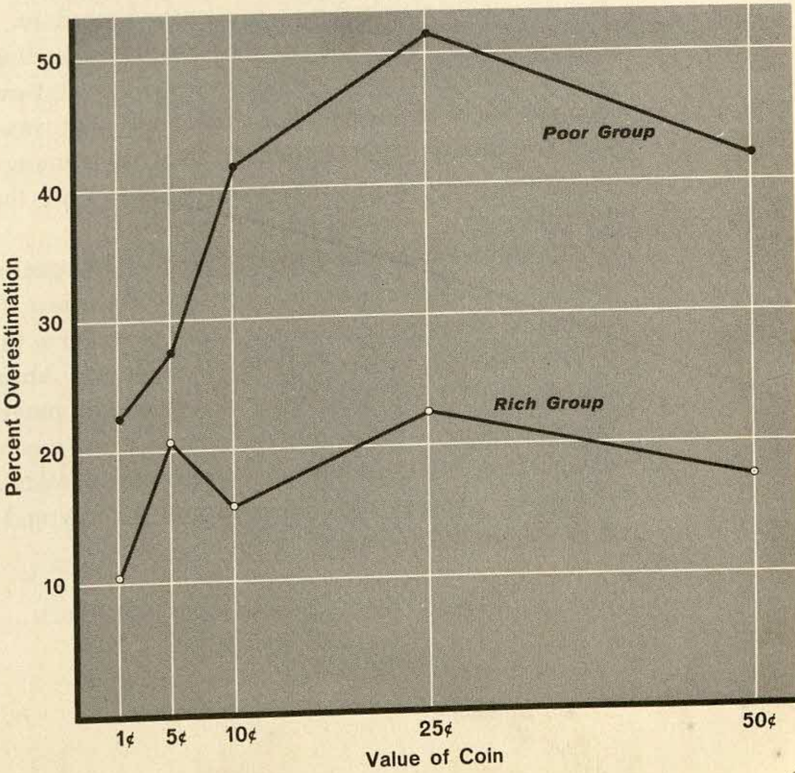
There are of course many other types of illusions than those of length and extent. Illusions of direction and shape are common. Although illusions pertaining to vision are best known, some illusions of other senses such as hearing and touch have been described. The existence of illusions means, in general, that there are a number of *exceptional stimulus-situations* in which our learned scales and models do not accurately reflect the world as determined by physical measurement. This fact should not blind us, however, from the realization that in most circumstances, the scales and models we have learned are fairly accurate and highly useful.

Motivational Factors

Motivational factors also can be shown to influence our identification behavior. Wishes and desires of which we are only partly aware may distort the scales and models we acquire in a direction away from "reality."

This kind of effect has been shown in a study of identification of coin sizes. A group of children were asked to adjust the size of an iris diaphragm to equal the size of each common United States coin. They were also required to match the size of the diaphragm setting to cardboard discs of the same size as these coins. It was found that the children matched the sizes of the discs with great accuracy, but they consistently overestimated the sizes of the coins. Furthermore, the larger-valued coins tended to be overestimated to a greater extent than smaller-valued coins. Thus the results demonstrate that models may be influenced by an individual's values, in other words, by his *motives*.

FIGURE 7.23. *Overestimations in the sizes of common U.S. coins by poor and rich children of age 10.* (After Bruner, J. S., and Goodman, C. C., Value and need as organizing factors in perception, J. abn. soc. Psychol., 1947, 42, 33-44)



As a further point, this study compared the overestimations of coin-size by children who were poor and by children who came from well-to-do families. There was a remarkable difference in the amount of distortion of the coin-size identification scale between the poor and rich groups, as shown in Figure 7.23. There can be little doubt that our acquired scales can be significantly affected by our motives. Other studies have obtained results leading to similar conclusions. For example, it has been found that the heights of mothers, fathers, ministers, and school principals tend to be overestimated by children in relation to their own heights.[5] The child perceives these people as powerful figures, and their heights are accordingly identified on a scale that distorts reality to some extent.

SUMMARY

This chapter deals first with the function of detecting small differences in stimulation, called *discrimination*. Second, it treats of the more complex function of *identification* (sometimes called *perception*), by means of which stimulus-changes of the physical world become organized into patterns of various kinds, including shapes, colors, and distances. Identifications are possible because of the existence of models and scales, which are largely learned.

A *threshold* of discrimination is defined as that value of the stimulus which is detected 50 percent of the time, and not detected 50 percent of the time. A threshold is measured by finding the median of a series of measurements obtained by a bracketing procedure. The *absolute* threshold refers to the value of the stimulus which can be discriminated as present or absent. The *differential* threshold is the smallest change required to make two stimuli be responded to as "different." This small change is symbolized as ΔX, where X is the physical value of the stimulus being changed. Often, interest centers in the proportion $\Delta X/X$, rather than in the quantity ΔX by itself.

Discrimination capacities of the human organism are described in this chapter for vision, hearing, and the other senses (insofar as data exist). Generally speaking, the human being is sensitive to very small amounts of physical energy, in all his sense departments. Absolute thresholds tend to pass through a minimum value in the middle range of detectable stimulation. Differential thresholds are often roughly a constant proportion of the value of the stimulus, but again, only in the middle range of stimulation. Higher proportions typically obtain at the low and again at the high end of the detectable range.

Identification of *distances* and *depth* can be based upon a number of different scales. There is a scale derived from kinesthetic cues provided by *accommodation,* the adjustment of the lens of the eye in focusing. Another source of kinesthetic cues is *convergence,* the movement of the eyes inward in their sockets, as well as *divergence,* the opposite movement. Then there are a number of *visual background* cues which can be the basis for learned scales and models. Among these are *binocular parallax,* and a number of *monocular cues.* An important one of this latter type is *linear perspective,* the shrinking of the visual image with (physical) distance. In addition, some well-known cues to distance perception are *aerial perspective, shadows,* and *interposition of objects.*

Distance identifications are typically made in terms of learned scales which may utilize any of a variety of standards from the individual's previous experience. In addition, most individuals acquire scales corresponding to common units of distance used in physical measurement, like feet and yards, which vary considerably from individual to individual. Training has been shown to be effective, however, in improving the accuracy of such scales, so that they can be brought into correspondence with physical scales.

The perception of size at a distance is presumably based upon a learned distance scale, and has been shown to be fairly accurate in normal individuals out to 4,000 feet. Objects tend to be perceived as slightly larger than their true size at this distance.

Other visual identifications that have been subjected to study are *numerousness, grouping,* and *shapes.* The identification of shapes appears to be based upon some models which are universally acquired, like the circle and the square. The stored models of more complex shapes, however, may resemble common objects.

Some examples of scales pertaining to hearing are found in the perception of sound directions, in avoidance of obstacles by the blind, and in the appreciation of music. An example of a set of models pertaining to the sense of touch is given by a group of distinctively shaped control knobs.

Scales and models are not perfectly accurate reflections of the physical world, although they are highly useful for most behavioral purposes. Some distortions from the ideals defined by objective measurement occur because of the influence of *stimulus factors* and *motivational factors.* The former condition results in exceptional kinds of identifications called *illusions.* Identifications are also affected by *motives.* Needed objects may be perceived as larger than they really are; powerful people may be identified as of greater height than they actually are.

READING REFERENCES

Bartley, S. H., *Vision: A study of its basis.* New York: Van Nostrand, 1941. An account of visual discrimination and its physiological basis.

Boring, E. G., *Sensation and perception in the history of experimental psychology.* New York: Appleton-Century-Crofts, 1942. The history of theory and experiment in discrimination and perception.

Chapanis, A., Garner, W. R., and Morgan, C. T., *Applied experimental psychology.* New York: Wiley, 1949. A textbook describing military and industrial applications of knowledge about discrimination and identification.

Geldard, F. A., *The human senses.* New York: Wiley, 1953. A comprehensive text providing descriptions of the physical stimuli, the sense organs, and discrimination behavior for all the senses.

Gibson, J. J., *The perception of the visual world.* Boston: Houghton Mifflin, 1950. A description and analysis of the sensory events underlying visual identifications.

Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954. A textbook with results of studies of discrimination and identification.

8

MOTOR SKILLS

Continuing our account of the classes of human behavior, we turn now to a consideration of motor skills. In this chapter you will first read about some of the limits imposed by human physiology on the human capacity for various kinds of motor activities. There are limits to the speed, to the force, and to the precision of human responses. We then examine how these responses become linked into motor-skill sequences. Major influences on the process of learning a motor skill are described. The transfer of training from one motor skill to another is analyzed. Finally, we discuss the retention of motor skills after periods of disuse.

Skills involving movement of the body and its members are highly important to human existence. Walking, talking, dressing, driving a car, and manipulating tools such as knives and forks and doorknobs are all such well-practiced activities that we seldom think about them. Yet an injured thumb or a broken leg or an attack of laryngitis can make us acutely aware of the gross deficiencies in everyday activities created by the temporary loss in ability to exercise certain essential motor skills.

As for the specialized performances required for the operation of machines and the use of tools in productive work, modern trends in machine design are tending to deemphasize human motor skills. Automatic transmissions and power steering in automobiles have changed considerably the nature of the skills required in driving. Motor skills formerly employed in many industrial operations have been eliminated by precision machines controlled by automation. Modern aircraft equipped with automatic flight control devices do not demand the kinds of motor skills which were needed in flying a light plane of 1930 vintage; even small modern planes do not require motor skills of the same sensitivity and scope as were previously needed. Military operations, it is said, have entered the stage of "push-button warfare."

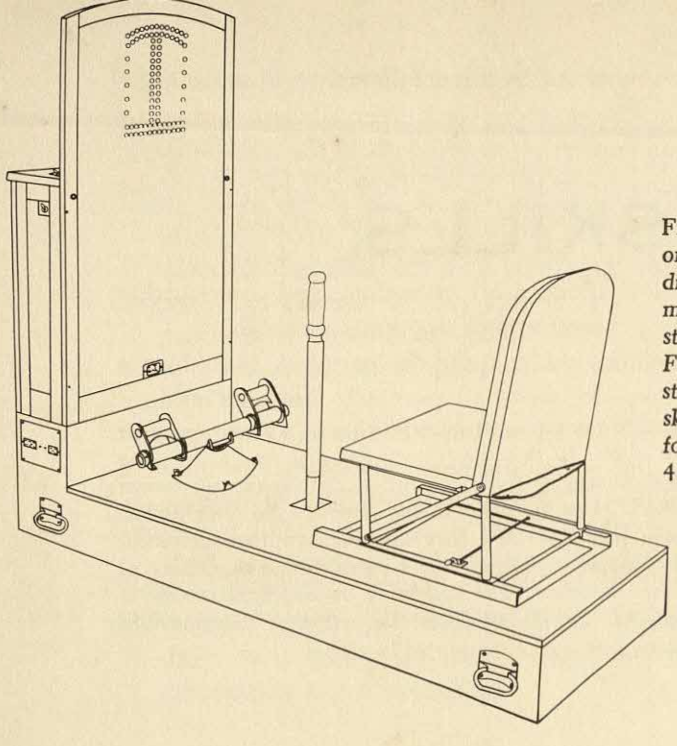


FIGURE 8.1. *The Complex Coordination Test. The subject coordinates stick and pedal controls to match the indicated positions of stimulus light patterns. (From Fleishman, E. A., A comparative study of aptitude patterns in unskilled and skilled psychomotor performances,* J. appl. Psychol., *1957,* 41, *263-272)*

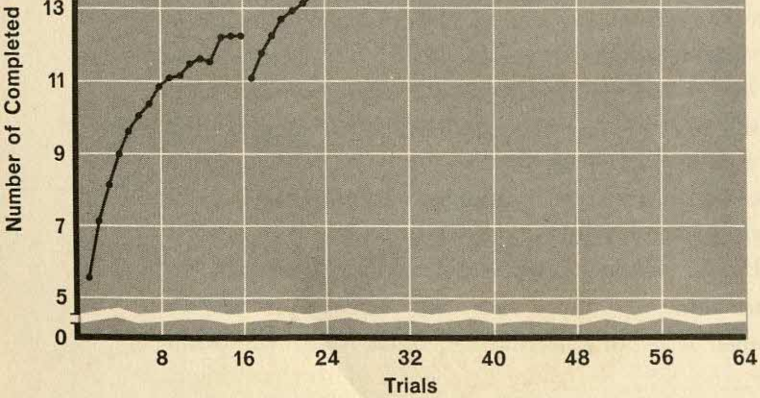


FIGURE 8.2. *Learning curve for 197 men who practiced on the Complex Coordination task for 64 two-minute trials distributed over two days. Rest between trials was one minute. Breaks at trials 16 and 38 are lunch hours. The break at trial 32 represents the overnight interval. (After Adams, J. A., The prediction of performance at advanced stages of training on a complex psychomotor task. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1953, Research Bulletin, AFPTRC 53-49)*

The assumption of motor functions by a machine may be economically desirable because the machine can do more work. Nevertheless, within the limitations imposed by human capacities, motor skills in the human operation of machines can be useful for many tasks. They can be precise, dependable, relatively free of error, readily acquired, and retained well over long periods of time. The smooth motor performance of a skilled operator may in certain instances be less conducive to boredom, and consequently less subject to gross error, than the activity of watching a machine.

Whether productive machines will require fewer motor skills in the future, we cannot say. If they do, we shall probably find men using a greater variety of motor skills in their leisure time. People will play a greater variety of sports and games, and engage in more hobbies that require tool using, such as carpentry, masonry, and various handicrafts. It is generally recognized that human beings have a need to engage in motor activities, whether these be vigorous sports like tennis or handball, or less violent activities like wood-carving. The exercise of skilled muscular activities appears to have considerable importance for mental health.

ABILITIES AND MOTOR SKILLS

In our discussion of human abilities in Chapter 5, we described the variety of basic motor abilities in which people differ. Such motor abilities support and facilitate a wide range of specific motor performances. Thus an individual with a high degree of manual dexterity is likely to do well a variety of specific tasks involving rapid, skillful arm-hand manipulations of objects. The abilities possessed by different individuals help to predict (a) the rate at which specific skills requiring these abilities are learned and (b) the final level of proficiency which is attained in these skills. Thus, the man with low ability in multiple-limb coordination may never make a really excellent pilot, even if he is given a great deal of flying training.

The relationship between the abilities that different people possess and the progress they make in learning a specific complex motor skill is illustrated by the results of a recent study. Two hundred young men learned to perform on the device pictured in Figure 8.1. This task presents a pattern of light signals on the upright panel, and requires the operator to match this pattern with another set of lights by moving the stick and rudder controls to appropriate positions. When all three controls are in the proper position at the same time, a new pattern of lights is presented. The subjects practiced this task over a two-day period. All improved markedly in skill on this task (see Figure 8.2) but some improved more than others.

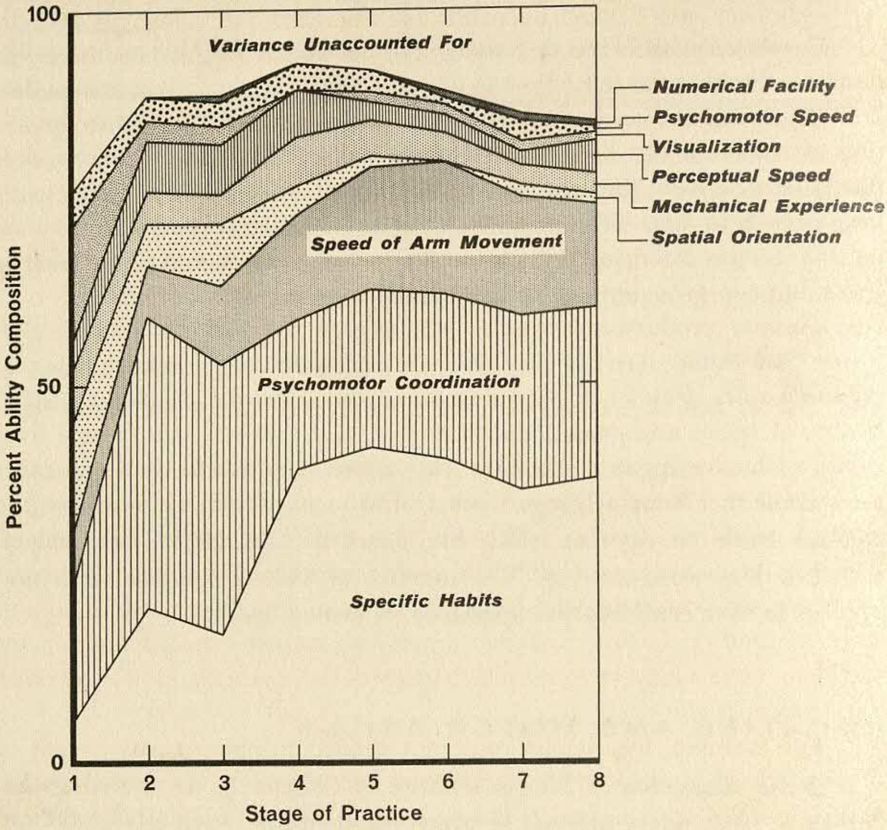


FIGURE 8.3. *Abilities contributing to performance at different stages of practice on the Complex Coordination Test. Percentage contribution at each stage is shown by the size of the shaded area representing each ability. These results refer to the performance curves shown in Figure 8.2. (From Fleishman, E. A., and Hempel, W. E., Changes in factor structure of a complex psychomotor test as a function of practice,* Psychometrika, *1954, 19, 239-252)*

The same individuals were also given a large number of basic ability tests. Using correlation techniques, it was possible to establish the relationship between these more general basic abilities and skill at different stages of learning this task. Figure 8.3 shows the importance of different abilities at successive stages of skill attainment.

It can be seen that multiple-limb coordination was important throughout. Spatial orientation and certain other abilities were important in the early stages of learning but not important later. Speed of arm movement was important in predicting advanced levels of skill, but not earlier levels. It is also evident that performance on this task came to be increasingly dependent on the skills which were specific to the task. In other words, while general abilities are important determiners of task performance, high levels of proficiency also depend upon how well different individuals profit from their experience with the task itself. Results similar to this have been obtained with other motor performances.

Thus, while general motor abilities are important in predicting performance on specific motor tasks, this is not the whole story. There is much we need to know about the specific motor skills themselves and the conditions which lead to effective performance in these skills. In this chapter we shall take a more detailed look at what motor skills are like and what is known about the conditions of their learning and use.

MOTOR SKILLS AND RESPONSE CAPACITIES

In Chapter 3, we pointed out that motor skills are learned *sequences of responses.* These sequences are learned and stored by means of the central neural mechanism which we have called the motor-skill memory. Since both specific motor skills and basic motor abilities depend on neural and muscular structures, the capacities of these structures must be considered as limiting factors. In other words, we cannot expect human motor skills to have characteristics which exceed the *capacity of the response mechanism itself.*

For example, the human responses needed to operate many types of equipment are a result of the contraction and relaxation of certain muscles. These muscles are attached to the skeleton in such a fashion that force can be applied to a control stick, lever, or foot pedal. In flying an airplane, the task consists of a number of such operations. It is known that man's capability in exerting force is limited. If, for example, he is required to exert more than 60 pounds of force against a control stick, we know the average man cannot do this. Consequently, the controls must be designed so that they do not exceed the capacity of the response mechanism in this dimension of *force.*

In today's modern aircraft it is not uncommon for two planes to close the gap between them at speeds of 1,000 miles per hour, or 1,460 feet per second. We know that the speed of activity required to avoid collision under such circumstances may often exceed man's speed of reaction to visual stimuli, which is of the order of one-quarter second. The task of moving his aircraft away from a collision course, once he has seen the other aircraft, is beyond man's response capacity. It is also known that the speed with which tapping movements can be made varies from 5 to 14 taps per second with a mean of around 8.5.[1] We cannot expect more complex skills based on these responses (for example, Morse-code sending) to exceed these response limitations in the factor of *speed.*

In addition to force and speed, there are definite limits in the *precision* with which certain responses can be made. For example, certain sets of muscles operate in opposition to each other to maintain equilibrium of the body members when they are held in a fixed position. The tensions set up result in tremor of the particular limb. People differ in the degree of muscular tremor they exhibit. We cannot expect a watch maker or welder to do a good job if this precision characteristic exceeds certain limits.

In the following sections, we shall describe some of the important response capacities which physiologically limit motor performances. The capacities which have been most extensively studied are those of speed, force, and precision, although there are other characteristics which could be investigated. Moreover, these capacities are usually measured for particular groups of muscles. Although some attention has been paid to leg and trunk movements, by far the greatest amount of data has been gathered for the movements of arms, hands, and fingers. For practical considerations of man's work and the design of machines and tools for it, this is quite understandable, since the greatest variety of useful motor performances is possible with these body members.

SPEED OF REACTION

Probably no type of measurement is so well known in the field of behavior as the measurement of *reaction time*. The original interest in the subject arose from a practical problem faced by astronomers in recording the time at which stars were seen to be coincident with a hair line of a telescope. Because different individuals reacted with different speeds to this observation, astronomers began to pay considerable attention to these differences, which they called the "personal equation." Later the problem of measuring speed of reaction was extensively studied by the early experimental psychologists. They believed that they would be able to measure the time required in "mental" events such as choice and judgment, by subtracting simple reaction time from the time required to react to more complex situations. The difficulties they encountered in this effort arose from the fact that the total time taken to make a reaction is influenced by many things. It varies with the stimulus employed, with the reaction mechanism used, and with certain factors which influence central neural functioning such as attention and general muscular tension.

As a result of all this study, it is quite evident that we cannot hope to measure speed of motor reaction separately from the time required in the reception and discrimination of stimuli, nor from central neural processes. This fact has limited importance, however, when we are interested in comparing the reaction speeds of different body members. In such a case, interest centers on the limits of human motor reaction, under certain standard conditions of attention and tonus of body musculature, to specific kinds of stimulation.

Measuring Reaction Time

In principle a device to measure reaction time is very simple. It is composed, first, of a stimulus-presenting mechanism. In the case of vision, this may be an electric lamp with an extremely short time for onset of glow; for hearing, a pair of headphones connected to a source of sound such as an oscillator. Second, there is a control to which the individual responds; commonly this is a key like a telegraph key, which the individual may be required either to release or to depress. Third, there is an accurate means of measuring the time interval between the onset of the stimulus and the completion of the response. Many kinds of devices can be used for this, but synchronous electric clocks which record time in thousandths of a second are sufficiently accurate for most purposes.

DEPENDENCE ON THE SENSE ORGAN. The speed of motor reaction varies with the *particular sense organ* receiving the stimulus. Presumably, differences in speed depend upon the different rates with which the receptor actions take place, and also on differences in the neural events of discrimination associated with each type of receptor. At any rate a general value for reaction time cannot be given; the sensory channel has to be specified. A summary of values for speed of reaction with an intermediate intensity of stimulation for the various senses is given in Table 8.1. Accurate measures for reaction time to odor stimulation and temperature sense stimulation have not been obtained.

TABLE 8.1
SPEED OF REACTION TO STIMULI OF INTERMEDIATE RANGE FOR DIFFERENT SENSES

SENSE	MILLISECONDS
Vision	180
Hearing	140
Touch	140
Taste	
Salt	310
Sweet	450
Sour	540
Bitter	1080
Pain	890

(Data from Woodworth, R. S., and Schlosberg, H. *Experimental psychology* [Rev. Ed.]. New York: Holt, 1954).

INTENSITY OF THE STIMULUS. The *intensity* of the stimulus also affects the speed of motor response. The stronger the signal (such as light or sound), the more rapid is the reaction time, as shown by the results of Figure 8.4. Here the reaction times of two observers are averaged. The stimuli were 1,000-cycle tones of intensity varied from near-threshold to 10 log units (100 decibels) above threshold. As can be seen, the time of response grows shorter as stimulus intensity increases. A small increase in intensity makes a large difference in reaction time at the lower intensities. At the higher intensities, there is proportionately less effect on reaction time by successive increases in intensity. As Table 8.1 shows, reactions to visual stimuli in the middle range of intensities ordinarily yield slower times than do reactions to auditory stimuli in the middle range. However, it is perfectly possible to get a visual reaction time faster than an auditory reaction time by increasing the intensity of the visual stimulus. For example, a very bright light will produce dependably faster motor responses than a 3,000-cycle tone at the low intensity of 40 decibels.

SUMMATION OF STIMULI. Reaction time is shorter with binocular than with monocular stimulation by the same light. Similar effects occur with auditory stimuli when the same sound is admitted to both ears rather than to one ear alone. However, if two different stimuli, a light and a sound, come on simultaneously, reaction time is no faster than the sound alone.

CHOICE REACTION TIME. If the individual must respond *differentially* to different stimuli, reaction time is increased. This, of course, is the more typical situation which occurs, for example, in driving a car. Figure 8.5 shows the results of an experiment with a well-practiced subject in which the number of alternative choices was increased from 1 to 10. In this study, the individual had to respond to an appropriate signal by pressing a designated key with one of his fingers (or thumbs). As the number of alternative choices increases, reaction time rises rather rapidly at first, then more slowly up to the ten-choice situation.

RESPONSE REQUIRED. Most reaction-time studies employ a finger or

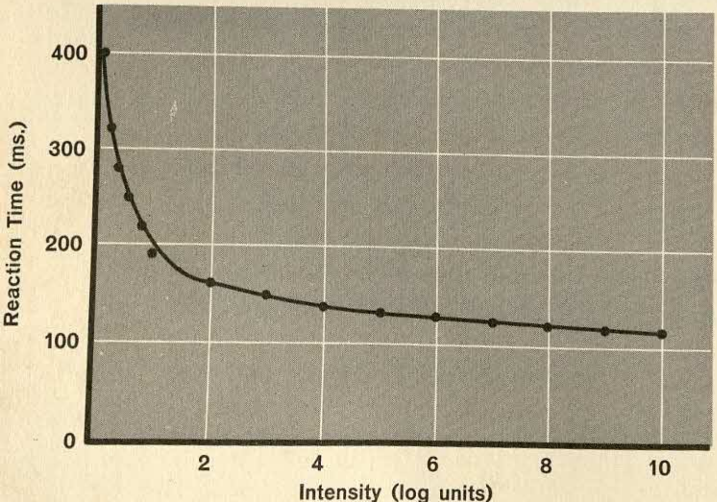


FIGURE 8.4. *Speed of response in milliseconds as a function of intensity of a 1,000 cycle tone. The reaction times of two individuals are averaged. (Data from Chocholle, R.,* Variation des temps de réaction auditifs en fonction de l'intensité à diverses frequences, *Ann. psychol., 1945, 41, 65-124)*

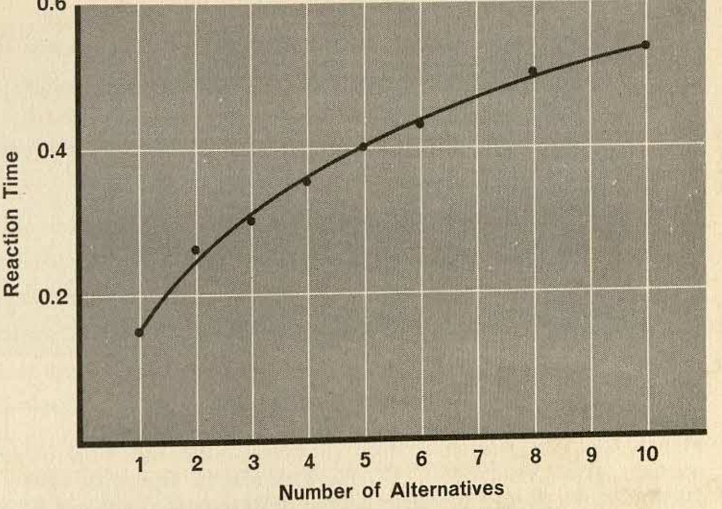


Figure 8.5. *The relation of time of reaction to number of choices. The task required the individual to press the correct one of ten keys on which his fingers rested. (Data from Hick, W. E., On the rate of gain of information,* Quart. J. exp. Psychol., *1952, 4, 11-26)*

hand movement. Responses involving other muscle groups have been measured, holding the type of stimulus constant. These findings indicate that reaction times of the two hands do not differ significantly from each other, nor do those of the two feet.[2] However, reactions of the feet are considerably slower than are hand reactions.[3] A biting movement has been found to give as fast a reaction time as a response with the hand.[4]

It should also be noted that correlations are high between reaction times made to different stimuli and with different responses. Individuals tend to rank themselves about the same on different reaction-time measures. There seems to be a trait of *reaction time* present in different degrees in different individuals, as we mentioned in Chapter 5.[5] However, this is not a general "speed" trait, for it does not correlate highly with other types of speeded motor acts.

Central Neural Effects in Reaction Time

The reaction time is also influenced by other kinds of events in the central nervous system. Some of these will be summarized here.

Motivation. Studies have shown that giving individuals incentives to react faster produces an increase in the average speed of response. When a reaction-time device was wired so that an electric shock was delivered whenever the speed dropped below a certain value, a significant decrease in average response time occurred. In one study, this arrangement decreased the average reaction time from .145 second to .118 second.[6]

Preparatory Set. When the individual is given a "ready" signal shortly before the onset of the stimulus, reaction time is shortened considerably. This fact is made use of in track events, where the runners are given the signal "on your mark, get set, go!" The ready signal is presumed

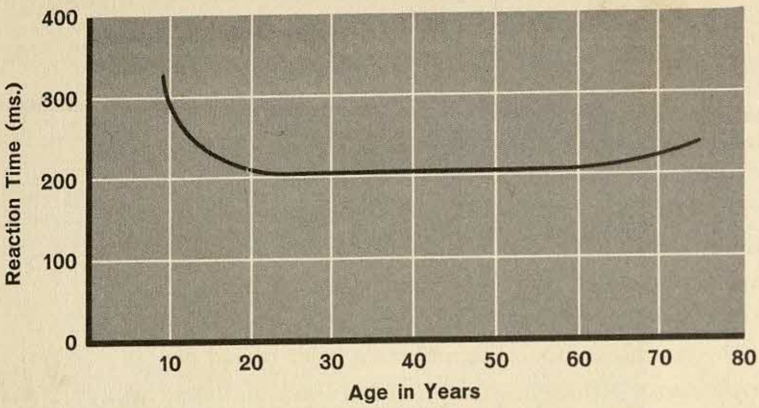


FIGURE 8.6. *The relation between chronological age and speed of motor reaction. (Data from Miles, W. R., Psychological aspects of ageing, in Cowdry, E. V. (Ed.),* Problems of ageing. *Baltimore: Williams and Wilkins, 1942)*

to establish a central neural state called a *set,* which is present during periods of high attentiveness. Use of a "ready" signal usually lowers speed of reaction to visual and auditory stimuli by about .05 second below the speed of reaction without such a signal. Greatest effects of such a signal are found if it precedes the stimulus by 1.0 to 2.0 seconds.

GENERAL MUSCULAR TENSION. Muscular tension throughout the body has also been found to speed up motor response. In one study, individuals were required to move a control stick to keep an indicator on a continuously moving target, and at the same time to lift a foot from a pedal when a light went on.[7] Electrical measurements of muscles in the brow were obtained by placing electrodes above each eye, and amplifying and recording these potentials. These served as indicators of level of muscular tension. The foot responses in this study varied in average time from 1.1 seconds at a low level of tension to 0.64 second at a high level of tension.

AGE. During early years, the speed of motor response continually increases as the nervous system approaches full maturity. In later years, some decrease in reaction time is noted, although this is not very great in absolute amount. Figure 8.6 summarizes the relationship between age and reaction time.

SEX. It has also been shown that men generally have faster reaction times than women, although the differences are not great.

FORCE OF REACTION

The force a man can exert in making different kinds of movements depends on the muscle groups involved. Even if the responses of a single limb are studied, a number of factors such as direction and length of movement affect the force with which the movement can be made.

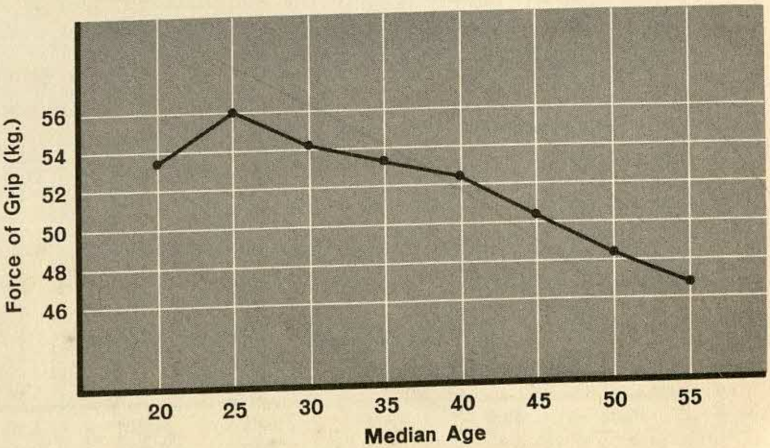
Measuring Force

A number of different devices have been developed to measure aspects of human strength. The simplest and most commonly used device is called a dynamometer. The force of the hand grip is applied against a spring-loaded handle by squeezing, and is recorded on a calibrated scale. This provides a measure of the maximum exertion obtained for a brief period of time. Consequently, such measures reflect a kind of upper limit of force which can be exerted. However, it has been found that such measures are correlated with measures of endurance (for example, the average strength in pounds that can be sustained for one minute). The dynamometer principle has been applied through various rigs to measurement of leg, arm, and trunk strength. Another device sometimes used to measure force is a strain gauge fixed to a stationary lever or handle.

GRIP STRENGTH. Data on the hand strength of boys and girls have been presented in Chapter 5. For the industrial worker the range of these forces is from about 75 pounds to 170 pounds, with an average of about 125 pounds. Figure 8.7 shows the relationship of age to force of grip.

ELBOW AND SHOULDER STRENGTH. A shoulder action is generally stronger than an elbow action. This was demonstrated by using a 17-inch handwheel which could be grasped in either of two ways: (a) with the forearm at right angles to the upper arm, or (b) with the arm extended to its full length. The handle was rigid, and force was measured by a strain gauge. It was found that rotation of the shoulder has approximately 1½ times the force of a rotation of the elbow.[8] It has also been found that in elbow

FIGURE 8.7. *Force of grip (kilograms) in squeezing a hand dynamometer measured in a group of male manual workers in industry. (Data from Fisher, M. B., and Birren, J. E., Age and strength,* J. appl. Psychol., *1947,* 31, *490-497)*



movements, a bending action is considerably stronger than a straightening action. Moreover, force with the bended elbow is greatest when the elbow is bent at right angles.[9]

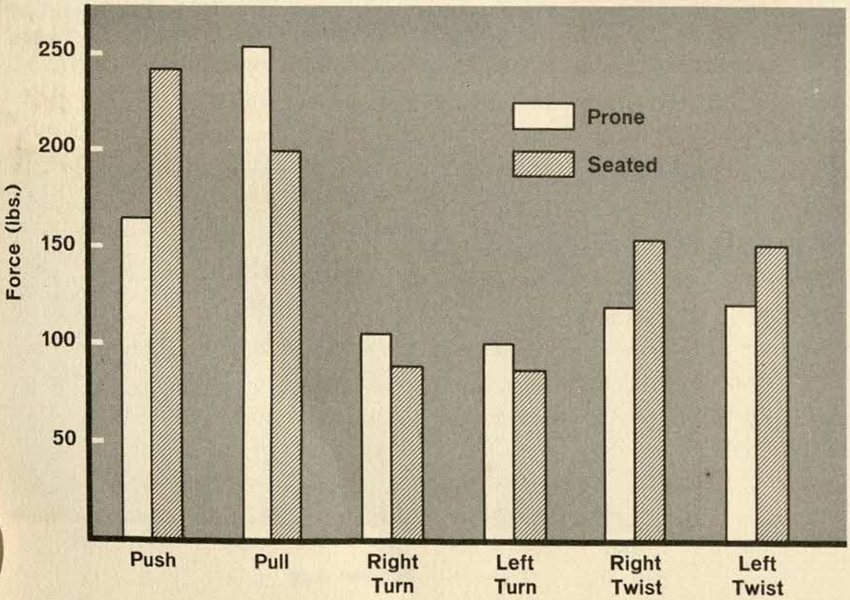
LEG FORCE. The force that can be exerted on a pedal, from a seated position, is generally greater than a person's body weight. One study showed that the average force which could be executed by the right and left legs on an airplane rudder pedal was 578 and 532 pounds, respectively. Since the standard deviation was about 100, this indicates that about two thirds of the 515 subjects exerted between 465 and 665 pounds.[10]

Individuals cannot maintain such forces, however. Subjects could maintain a 200-pound force for about 3½ minutes, but they could hold a 500-pound force for only 39.6 seconds. It has also been found that maximum leg force can be exerted when the knee is bent at about a 160° angle; in other words, when the pedal is not very far below seat level.

ARM FORCE. When a man is seated at a stick control, he can make movements of greatest force by horizontal pushing movements.[11] After this, in order of strength, come horizontal pulling movements, up movements, down movements, lateral movements in toward the body, and finally lateral movements away from the body. In a horizontal pushing movement, greater force can be exerted straight ahead than at any angle to the side.

FORCE IN CONTROL MOVEMENTS. The force of muscular movement is frequently measured in connection with the operation of some particular set of controls, in order to insure that design of machines does not exceed

FIGURE 8.8. *Force of motor responses in executing six types of control-stick movement in prone and seated positions. Average forces for 65 military pilots are shown. (Data from Brown, C. W.,* et al., Magnitude of forces which may be applied by the prone pilot to aircraft control devices. *USAF Air Materiel Command Memorandum Report MREXD-694-4J, March 1949)*



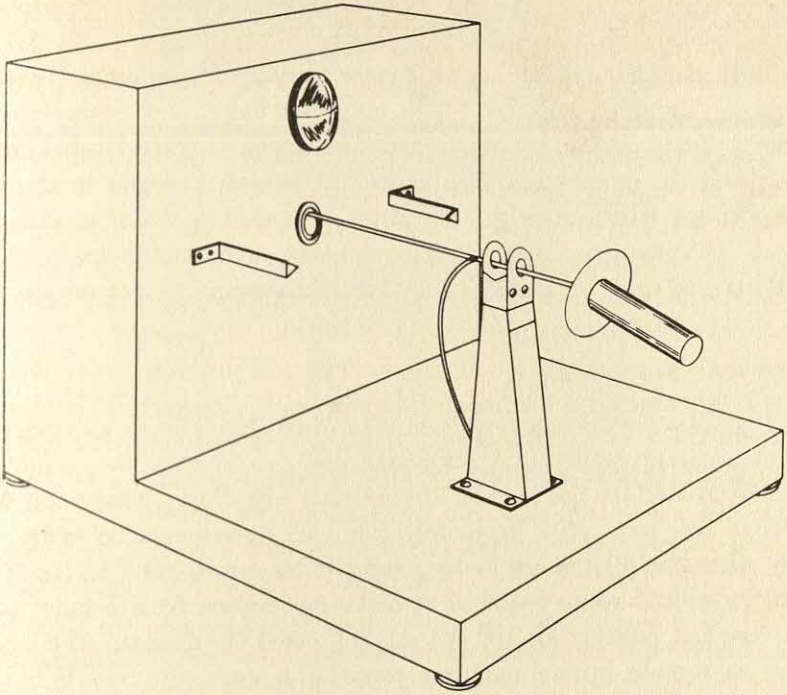


FIGURE 8.9. *The Steadiness-Aiming Test. (From Fleishman, E. A., A factorial study of psychomotor abilities. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, Research Bulletin AFPTRC-TR-54-15, 1954)*

human capacities. For example, in one such study, some special types of force measurements were made of military pilots, to obtain data for use in the design of aircraft controls in prone-position aircraft. For this purpose, the forces of push-pull, turn, and twist movements of a control stick were measured. The data are illustrated in Figure 8.8.

PRECISION OF RESPONSE

Besides speed and force, another limiting factor of the response mechanism is the precision of the movements which can be made. For example, how steady can a person hold his arm? How accurately can a reaching movement be made? How smoothly can a person move a very sensitive control? We will mention here a few of the ways such problems have been studied.

TREMOR AND STEADINESS. The precision of responses involved in holding a limb or other body member in a fixed position has been measured by devices such as the one shown in Figure 8.9. The individual is required to hold a $1/8$ inch stylus on a fulcrum within a hole $3/16$ inch in diameter. The number of hits against the sides of the hole is taken as a measure of steadiness.

Most muscles exhibit a fine tremor varying in frequency with the weight of the body member. The extended finger, for example, has a tremor of 10-12 oscillations per second, and of course the extended arm has a much slower tremor rate. We know that tremor increases in amplitude during strong emotions (e.g., "the jitters") as well as under conditions of fatigue. It follows that controls in equipment, such as high-speed aircraft, should not be made so sensitive they fall within man's tremor ranges.

Positioning Movements

A great many human responses involve reaching out or moving a control to a certain position. Anyone who has peered into the cockpit of a commercial airplane has seen an arrangement requiring a good many movements of this sort. How accurately can such movements be made, especially when the pilot is not looking right at his movement? In one experiment, individuals were required to make movements from a point of rest to a terminal position located 0.6, 2.5, 10, or 40 cm distant. These movements were made in total darkness, preceded in each case by a brief visual observation of the *extent* of the distance to be moved. It was found that people overshoot short movements (e.g., 1 to 4 inches) and undershoot greater movements (4 to 15 inches). Figure 8.10 presents some additional results. This figure shows that the percentage error is greater for the short arm movements and decreases markedly for the longer movements. It is also shown that positioning movements are more accurate away from the body than toward the body.

In many positioning movements, discrimination of the *direction* of

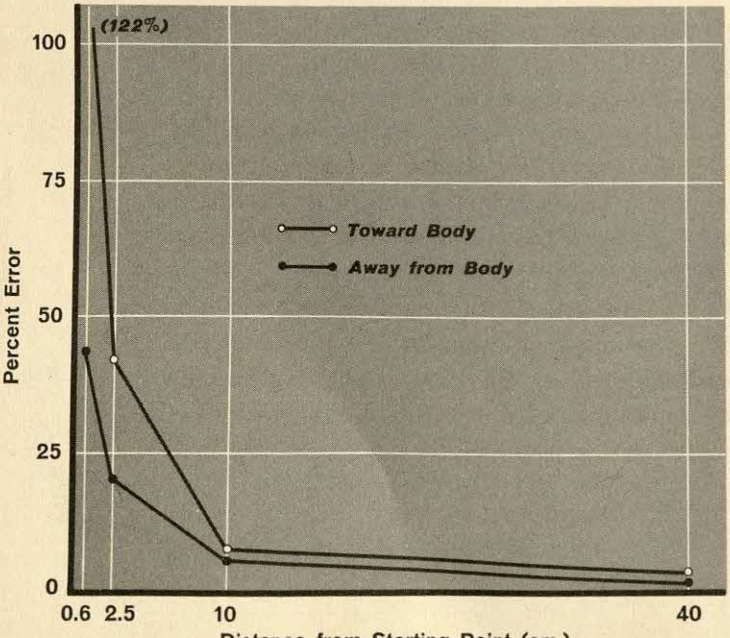


FIGURE 8.10. *Percentage error in positioning responses as a function of distance from the starting-point for movements toward and away from the body. The data are averages from 24 individuals. (After Brown, J. S., Knauft, E. B., and Rosenbaum, G., The accuracy of positioning reactions as a function of their direction and extent, Amer. J. Psychol., 1948, 61, 167-182)*

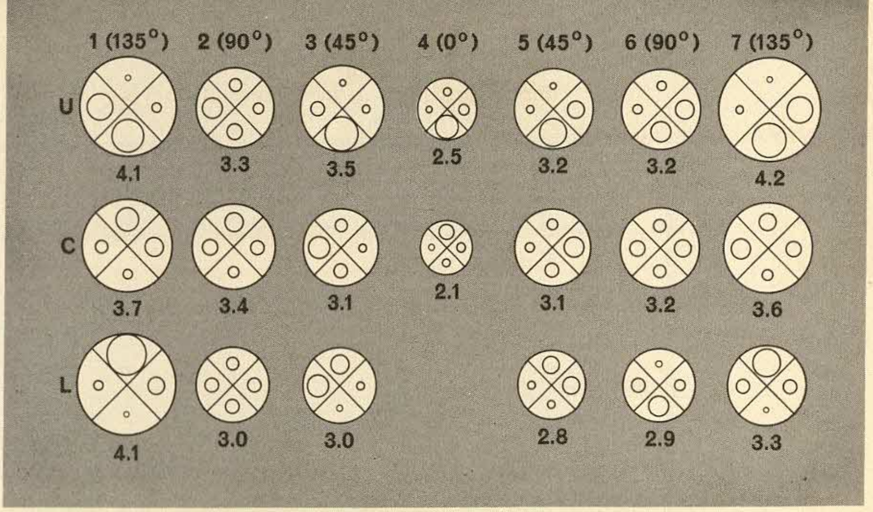


FIGURE 8.11. *Accuracy scores for different areas in a positioning study. The position of the circles represents the location of the targets, which range from 135° left (target 1) to 135° right (target 7) with number 4 straight ahead. The three rows represent those in the upper, center, and lower tiers. The size of each circle shows the relative number of errors; thus, small circles indicate greater accuracy (precision). The relative size of the inner circles indicates the errors in each quadrant of each target. (From Fitts, P. M. (Ed.),* Psychological factors in equipment design. *AAF Psychology Program Report No. 19. Washington, D.C.: U. S. Govt. Printing Office, 1947)*

movement rather than the *distance* of the movement is critical. In one study, blindfolded individuals were seated in front of a number of targets and required to make movements in different directions in order to hit them. The targets were placed around the subject at 0, 45, 90, and 135° angles right and left, in three tiers, one tier at middle level and the other two tiers at 45° above and below this. In response to verbal instructions the subjects attempted to strike the designated targets with the point of a pencil held in the hand. Figure 8.11 shows that positioning movements can be made with greatest accuracy straight ahead and below shoulder height. There is least accuracy in side positions, although right-hand targets can be reached with a little more accuracy than left-hand targets. With regard to the level of the targets, accuracy is greatest for the lowest tier, average for the middle tier, and poorest for the upper tier.

Continuous Movements

In making continuous adjustive movements, there is a built-in "lag" in the response mechanism which limits the precision of the movement. To illustrate, when a person is tracking a moving target in a gun sight and it changes direction, there is a measurable interval before the start of his corrective movement. Then he may overcorrect and actually swing past the

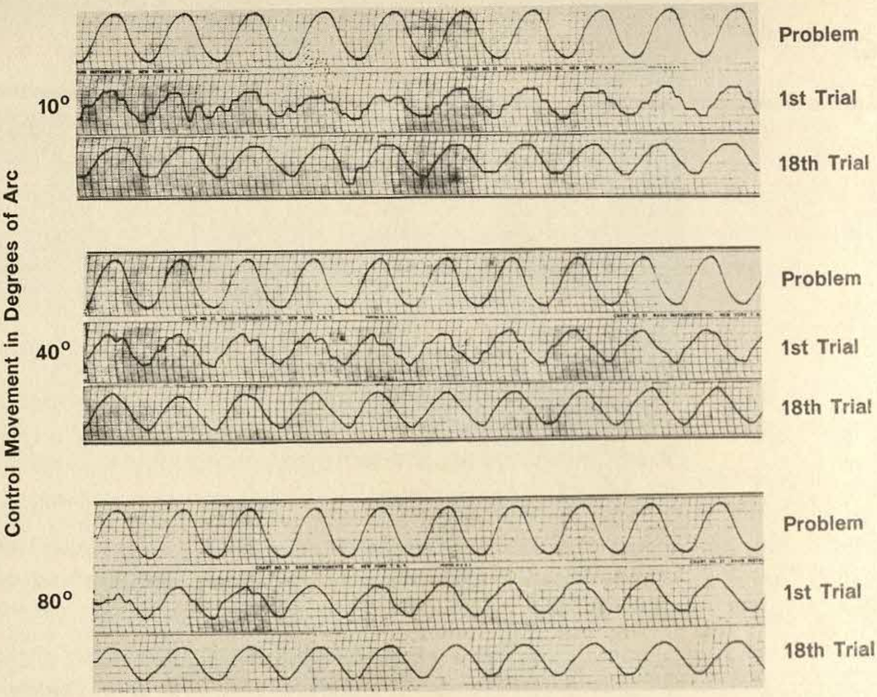


FIGURE 8.12. *Typical graphic records of continuous arm-control movements. The target dot on the scope oscillated right and left at 15 cycles per minute. This figure shows the discrepancy between the arm movement and the actual stimulus-pattern generated. When the arm control moved only in a 10° arc, it is seen that response precision was low on trial 1, but much more like the stimulus-pattern by trial 18. As can be seen, performance was better than this with a 40° control arc, and better still with an 80° control arc. (From Fitts, P. M., Marlowe, E., and Noble, M.,* The interrelations of task variables in continuous pursuit tasks: I. Visual-display scale, arm control scale and target frequency in pursuit tracking. *Lackland Air Force Base, Texas: Human Resource Research Center, Research Bulletin 53-34, 1953)*

target before swinging back again. Thus, movements of this type typically involve a response oscillation which can be characterized by (a) wave length, (b) amplitude, and (c) initial error. Each of these measures may be thought of as measures of precision of certain continuous movements. Sometimes a composite measure such as "time-on-target" is used.

Figure 8.12 gives an example of some records taken from a task in precision of continuous movement. The individual was required to move an arm control in order to keep a circle superimposed around a target dot, which moved from right to left and left to right in a simple side-to-side motion pattern on an oscilloscope. Moving the arm control to the right moved the circle to the right, moving it to the left moved the circle to the left. Differences between the stimulus-pattern and the subject's response-pattern can be seen. The response-pattern approximates the actual stimulus-pattern more closely as practice proceeds, but there are still differences after 18 trials. In designing equipment it is often important to know how to design a control system in order to maximize such accuracy. In the case of the task described, for example, increasing the arc over which the arm control could be moved resulted in an increase in the individual's response precision.

MOTOR-SKILL SEQUENCES

We have now reviewed some of the characteristics of the response mechanisms which place limits on the attainment of motor skills. We turn now to the skills themselves. We have previously pointed out that the individual responses which make up a skill come to be hooked together in sequences. We need now to examine in detail the nature of the sequences themselves, before discussing the principles applying to the learning of these sequences.

First, we know that the stimuli which set off responses in the skill sequence may be *internal,* such as kinesthetic or muscle sense stimuli. Other sequences depend more on *external* stimuli, such as visual or auditory cues. Whether the skill cues are internal or external, it is often possible to identify *discrete* (or *discontinuous*) responses within the sequence. In other instances, this may be impossible because the responses are *continuous* reactions to continuously varying stimuli.

Internal-External Control

The degree to which the individual responses that make up a skill are controlled by external stimuli is an interesting and important factor in motor skills. The two extremes of this dimension are illustrated in Figure 8.13. Skill A is one in which each response in the sequence is set off by a new external stimulus. In Skill B, on the other hand, only the initial response in the sequence is set off by an external stimulus—the remainder of the sequence "reels itself off" under the control of kinesthetic stimuli produced by previous motor responses. Frequently, skills are like Skill C, as shown in this figure. Here, the signal which sets off successive responses is a complex consisting of both an external stimulus and a kinesthetic stimulus arising from the previous movement. Skills of this type are perhaps the most common of all.

Let us consider some simple examples of skills of each type. Skill A may be represented by the task of drawing a square with pencil on paper. The initial stimulus (S_1) is provided by the sight of the pencil point and

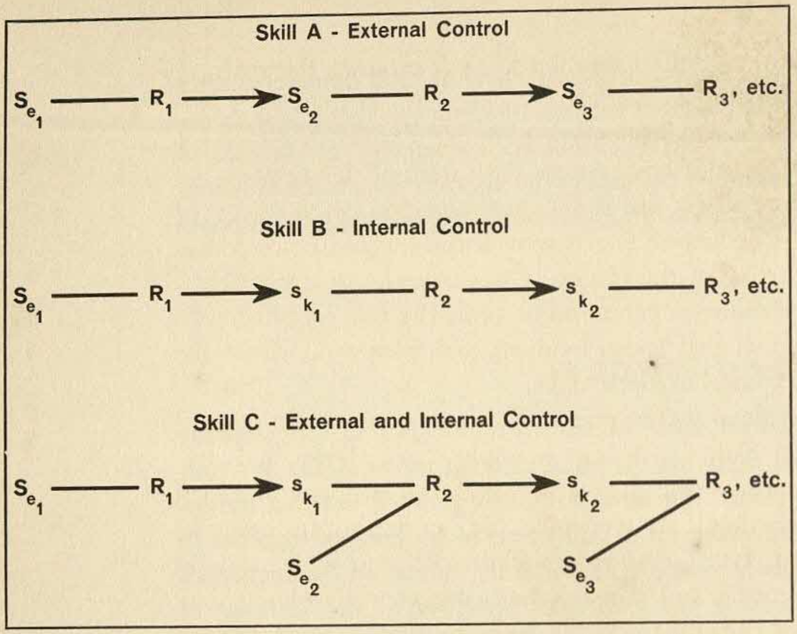

Skill A - External Control
S_{e_1} — R_1 → S_{e_2} — R_2 → S_{e_3} — R_3, etc.
Skill B - Internal Control
S_{e_1} — R_1 → s_{k_1} — R_2 → s_{k_2} — R_3, etc.
Skill C - External and Internal Control
S_{e_1} — R_1 → s_{k_1} — R_2 → s_{k_2} — R_3, etc.
S_{e_2}
S_{e_3}

FIGURE 8.13. *External vs. internal control in a motor skill. In Skill A, successively presented external stimuli (S_{e_1}, S_{e_2}, S_{e_3}) are associated with individual Responses (R_1, R_2, R_3) in the skill sequence. In Skill B, only the first response (R_1) is set off by an external stimulus (S_{e_1}); successive responses in the sequences are associated with internal kinesthetic stimuli (s_{k_1}, s_{k_2}) arising from the previous movement. Skill C represents a mixed type which is very common. After the initial response is set off by an external stimulus (S_{e_1}), successive responses are associated with a stimulus complex which contains an external stimulus (S_{e_2}) plus the kinesthetic stimulus (s_{k_1}) arising from the previous movement.*

the writing surface. (For simplicity, we will ignore the tactual stimulation which is present.) This leads to the response (R_1) of drawing a straight line. This line, plus the sight of the pencil and writing surface, now becomes S_2 and leads to the drawing (R_2) of another line at a right angle to the first, and of the same length. Now these two lines at right angles become the controlling stimulus (S_3) for the next response of drawing the third side of the square. And so on until the figure is completed. Now, it is evident that kinesthetic feedback does occur in this situation; obviously the movement of the hand in drawing a line can be responded to as a stimulus. But it probably does not function as a controlling stimulus. The length of lines, the angles which they describe, are determined by visual stimulation. No one who was trying to achieve an accurately drawn square would "trust" his muscles rather than his eyes. In other words, this particular skill is almost entirely under external control.

If we blindfold the individual, prevent his hand from touching the surface, and set him the task of drawing a square, we come very close to the situation of Skill B. Here the initial stimulus (S_{e_1}) is external, the pressure of pencil on paper. This leads to the first response (R_1) of drawing a line. This movement produces a kinesthetic stimulus (s_{k_1}) which is associated with the next response (R_2). The direction and extent of this response, in other words, are determined by the stimulation provided by the "feel" of the previous response. The same thing is true of the succeeding responses which complete the drawing of the square. Of course, the square which is drawn, although recognizable, is not as accurate as the one executed with visual control. But the fact that it can be done, and fairly well, shows the effectiveness of internal control in motor skills.

Most motor skills depend on the presence of both external and internal stimuli, as illustrated in Skill C. As our examples have shown, it is frequently possible to determine the degree to which the accuracy of a skill decreases when external stimuli are removed. We can do this, for example, by requiring a typist to "type" a sentence blindfolded and with hands in midair; or by asking someone to throw darts at a target while blindfolded. On the other hand, it is difficult to do the opposite, that is, to deprive an individual of internal stimulation. This would require some rather complex surgery or drug-injection techniques, and we would have difficulty insuring that only the nerves conducting kinesthetic impulses (as distinct from tactual or motor) had been blocked. Because of this, the evidence concerning the relative importance of internal control in any specific skill is usually indirect.

Much of the early research on maze-learning by rats was carried out to determine the extent to which such performance is controlled by internal stimulation. The learning of a maze by a white rat is characterized by a progressive increase in speed of making correct turns in the maze, and progressive decrease in wrong turns (blind alleys). It was found that maze skills are largely controlled by external stimuli, such as visual, auditory, and olfactory cues. When rats are deprived of these cues (through surgery or other techniques) and must depend on kinesthetic (internal) cues, they do not learn mazes very well. This is illustrated in Figure 8.14. This finding dispels the idea, once widely held, that maze skills are kinesthetically controlled.

There is some evidence that kinesthetic impulses can play an important role only after learning on the basis of external cues has begun. In many human motor skills, high levels of proficiency may depend more and more on such internal cues as learning continues. The novice golfer, for example, checks his grip visually, lines up his club head repeatedly, and makes many superfluous adjustments based on what he sees. It is only

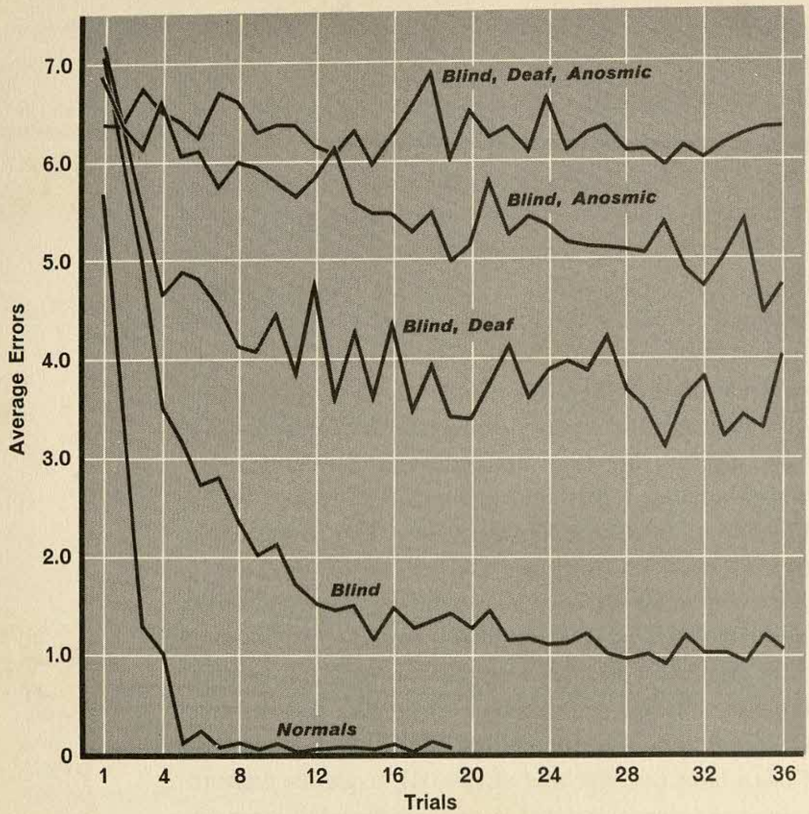


FIGURE 8.14. *The maze performance of rats deprived of various sensory functions. (Data from Honzik, C. H., The sensory basis of maze learning in rats,* Comp. Psychol. Monog., *1936, 13, No. 64)*

when the internal cues have become dependably sorted out that the golfer can achieve a consistent swing and a reasonably satisfactory score.

In sports such as baseball, golf, and tennis, the importance of "form" and "stance" has long been recognized and emphasized by expert teachers of the skills which make up these activities. Striking a golf ball with a club is not a difficult skill, and one which most adults can perform quite adequately. The direction of the club's movement can be controlled by responses that are set off by external visual stimulation provided by the ball, the ground, and the stick as it descends. But the skill of striking a golf ball so that it will travel in the desired direction and to the desired distance is something else again. This skill requires the reinstatement of motor responses which have the right "feel," in other words, which are associated with the proper (internal) kinesthetic stimuli. The emphasis by golf teachers on stance and form represents an attempt on their part to establish the individual practice habits which make for correct internal control of the skill.

Continuous and Discontinuous Skills

Drawing a square (visually controlled) is an example of a discontinuous skill in which the individual responses in the total sequence may readily be identified with the four sides of the square. Drawing a circle, on the other hand, is a continuous skill made up of individual responses which are impossible to denote exactly. What extent of arc should we consider a single response in this total sequence?

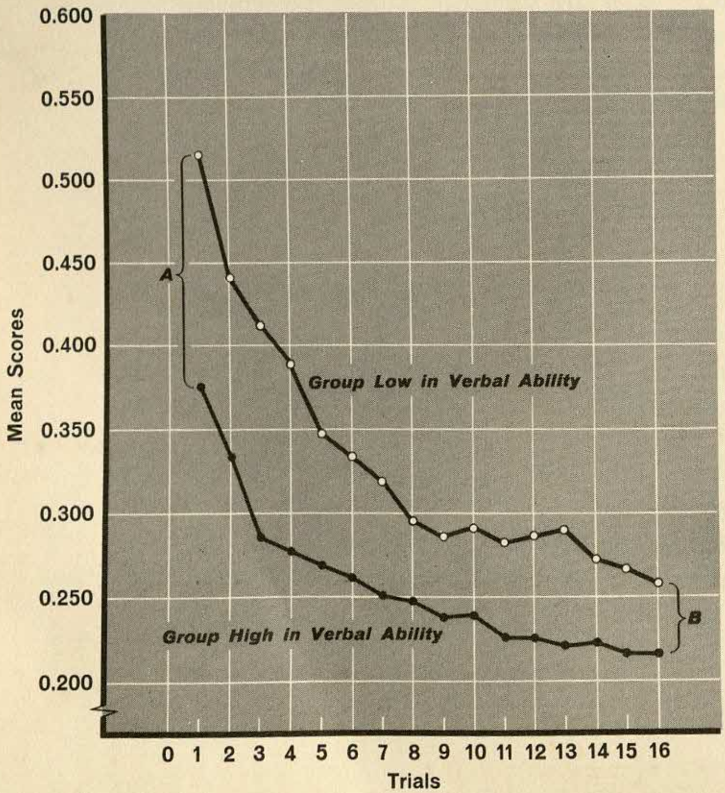
Similarly we cannot precisely identify the individual responses which make up such skills as hitting a golf ball, riding a bicycle, hurling a javelin. The responses in these skills are graded adjustments to external and internal stimuli which vary continuously, rather than discontinuously. Walking, although it partakes of the character of a continuous skill to some extent, may nevertheless be broken up into unitary responses which describe it quite well (see Chapter 3). It is interesting to note that high degrees of skill in swimming are attained when the movements of legs and arms are considered and practiced as sequences of discrete responses, a given number of leg beats to an arm movement. Here, it appears, is an example of a skill in which the all-important internal control can most readily be acquired through practice when the total sequence is deliberately broken into a set of discrete responses. This is not to deny that swimming has a continuous character to it, just as walking does. But the sequencing of the discrete responses of arms and legs appears to be one of the most important things for the learner to practice.

In contrast, many common skills are primarily of the discontinuous sort. This is true of playing musical instruments, where each successive note is a stimulus to be associated with a unitary response; and of typing, where each letter is the stimulus for a response to a given key. The maze skill of animals, referred to earlier, is a discontinuous skill in which each discrete unit of response is a turn to the right or left, depending on the presence or absence of a blind alley at the end of each turn.

The sequence of discontinuous skills is often controlled by verbal stimuli. Typing provides an example in which the successive letters or words in a sentence may be said to oneself and thus become stimuli for the next responses in the sequence. (This verbal stimulation constitutes another, and different, kind of "internal" control from the kinesthetic control we have previously described.) The usual external stimuli are either replaced by, or accompanied by, verbal stimuli. Thus, in typing the word "bear," the individual who is learning the skill may say "b" to himself after seeing the letter b on the page from which he is copying, and this verbalized "b" becomes the stimulus for the appropriate response. At a higher stage of skill, the individual may be able to say the word "bear" to himself and make the required set of responses of striking the keys b, e, a, and r. Playing a musical instrument is another example of a skill in which this type of verbal control occurs.

William James proposed the theory that the verbal stimuli used by an individual to set off response-sequences during early stages of acquiring a skill gradually drop out as practice continues and the skill becomes automatic.[12] According to this idea, in the beginning the learner sees the letter *b,* says to himself the word *b,* which then is associated with the response of striking the correct key. Later on, when the skill has been highly practiced, there is a short-circuiting effect in which the letter *b* leads immediately to the correct response without the intervening verbal stimulus ***b***. Despite several attempts, no one has been able to obtain direct evidence to support this appealing theory. It has been found, for example, that when a highly skilled typist is stopped suddenly in the middle of a word, he is perfectly able to state verbally what the next letter should be. So the verbal component apparently does not "drop out" completely; at least it can be recovered immediately by the skilled individual. Nevertheless, it is prob-

FIGURE 8.15. *Performance scores (speed of reaction) on the Discrimination Reaction Time Test for two groups differing in verbal ability. The difference in the curves early in learning (point A) is larger than the difference later in learning (point B). (After Fleishman, E. A., and Hempel, W. E., The relation between abilities and improvement with practice in a visual discrimination reaction task,* J. exper. Psychol., *1955, 49, 301-312)*



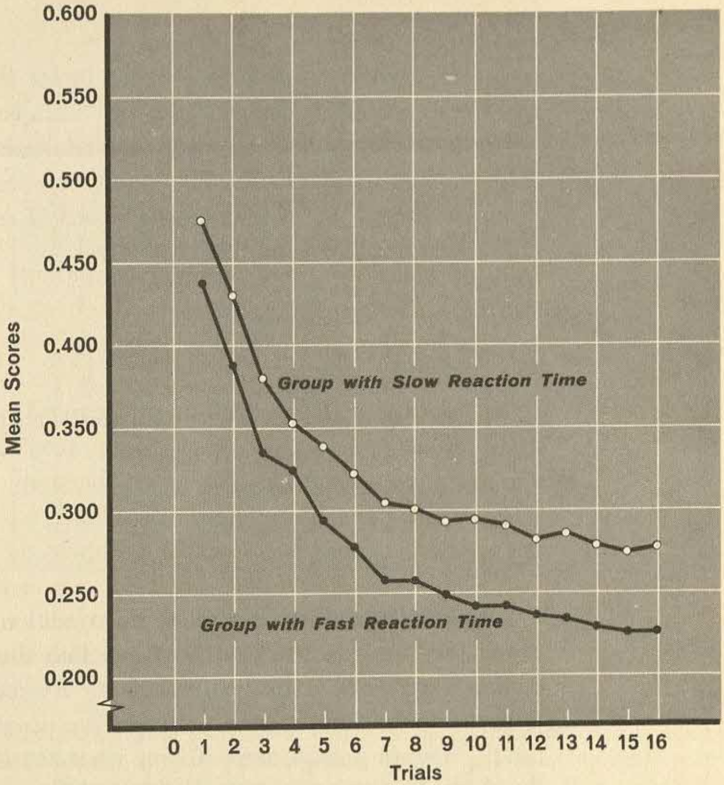


FIGURE 8.16. *Performance scores (speed of reaction) on the Discrimination Reaction Time Test for two groups which differ in reaction time. The curves separate, indicating that reaction time is an important ability at advanced proficiency levels on this task, but not at early stages of learning. (After Fleishman, E. A., and Hempel, W. E., The relation between abilities and improvement with practice in a visual discrimination reaction task,* J. exper. Psychol., *1955, 49, 301-312)*

ably true that the intervening verbal stimulus, while it doesn't disappear entirely, plays a decreasingly important role in controlling a skill sequence as the skill is practiced more and more.

Evidence for the decreasing importance of verbal abilities in learning motor skills is shown in Figure 8.15. The task required the individual to manipulate one of four different switches, as quickly as possible, in response to different combinations of red and green lights. If the red light was below the green light, the bottom switch was correct, if the red light was to the right of the green light, the right-hand switch was correct, etc. A different stimulus-pattern was presented every three seconds. Scores of all the subjects were also obtained on a standard test of verbal ability. The learning curves on the device were then plotted separately for those subjects who were above average on verbal ability and those who were below average on verbal ability. Figure 8.15 shows that early in learning those with high verbal ability did much better on the motor skill. However, verbal ability was not as important later in learning. Compare these results with those of Figure 8.16. Here the group was divided according to their previous scores on a reaction-time task. We see here that whereas verbal abilities decrease in importance as practice proceeds, speed of reaction becomes increasingly important in determining skill on this task.

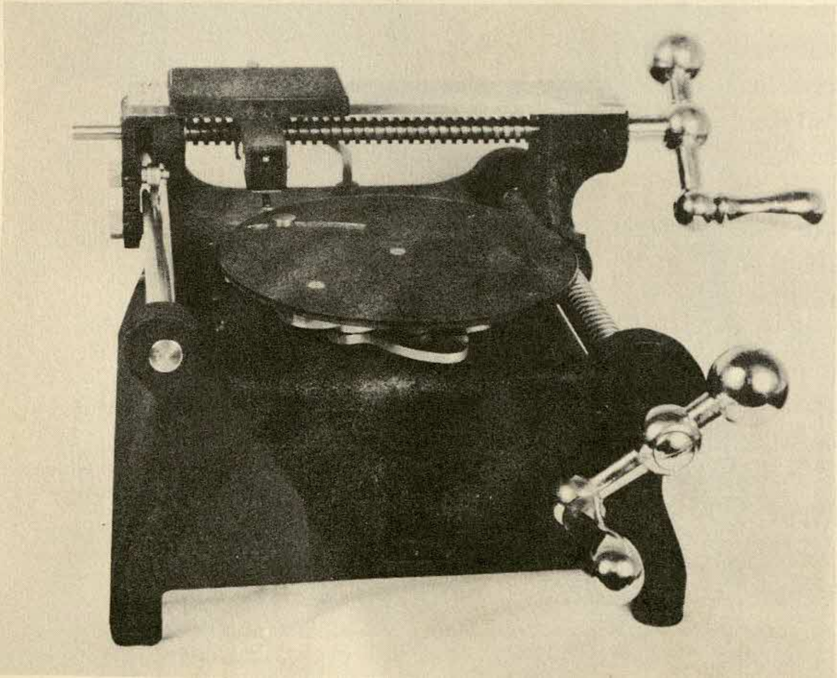
THE LEARNING OF MOTOR SKILLS

Now that we have seen what motor skills are like, we need to examine the question of how they are acquired. What conditions make possible the efficient learning and retention of motor skills?

Practice

As we learned in Chapter 6, no condition is of greater importance to the acquisition of motor skills than practice, that is, repetition of the desired response-sequence with reinforcement. Available evidence indicates that improvement in motor skills with practice usually continues for a long, long time. This, of course, depends on what the standards are for mastery of the skill. Many motor skills are learned to practical mastery within a relatively short period of time. Learning to swim so that one can stay afloat does not require much practice. But if the standards of mastery are raised

FIGURE 8.17. *The Two-Hand Coordination Test.*



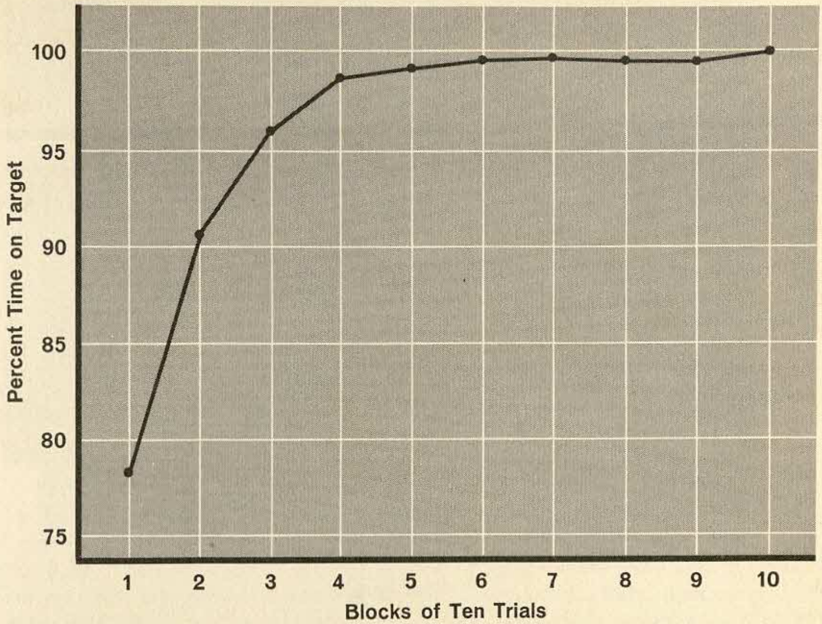


FIGURE 8.18. *Average time-on-target scores for ten young men in practicing the Two-Hand Coordination Test for 100 trials each of one minute's duration. In this study, the test had a movable button of 0.5 inch diameter, and a target disc of 0.875 inch diameter. Over 99 percent mastery was attained by trial 50, and 100 percent by trial 95. (Data from Wulfeck, W. W., Learning the two-hand coordination test,* J. appl. Psychol., *1942, 26, 41-49)*

to those of breaking time records, the effects of practice in improving performance may be observed over a period of years.

Figure 8.17 pictures a task called the Two-Hand-Coordination Test, in which the learner rotates a pair of handles to move a small button in two dimensions. One handle moves the button right and left and the other moves it toward or away from the operator. Coordinating the movements of both hands can move the button in any resultant direction. The task is to keep this button in continuous contact with a round metal disc which moves in an eccentric circular pattern. As Figure 8.18 shows, this task can be arranged so that practical mastery is achieved in a relatively short time. The average learning curve for 10 young men is illustrated, showing that near-perfect performance was achieved by trial 40, and 100 percent scores by trial 95. The standards for this task could be raised, and performance improvement could continue to be measured, by decreasing the size of the target disc, for example, or by increasing the speed of target movement.

A task whose limits are defined so that improvement can be observed over a longer period is the fencing lunge to a target of 9 concentric circles of diameter increasing from 1½ to 13½ inches. This task was practiced twice a week during 45-minute periods, and sample performance measures

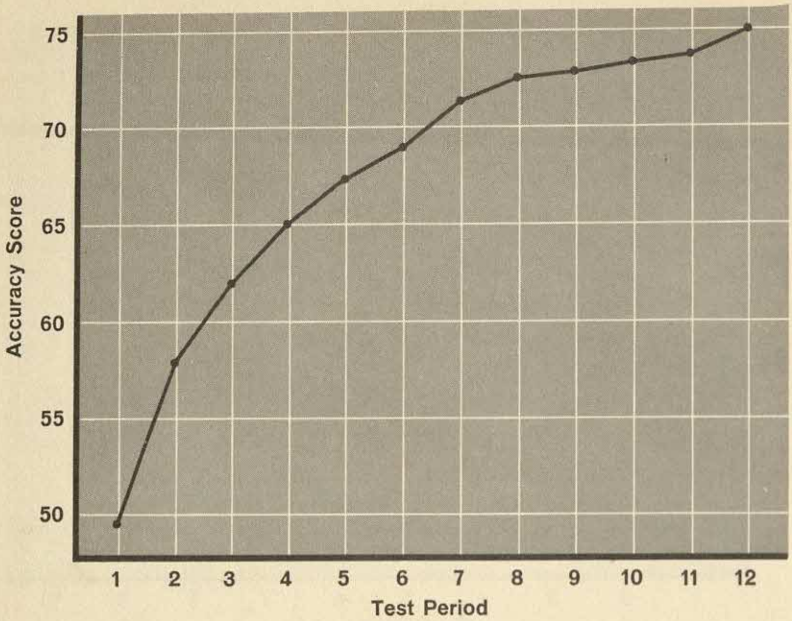


FIGURE 8.19. *Sample performance curve illustrating the learning of the fencing lunge to a target divided into concentric circles of diameter 1½ to 13½ inches. Scores assigned were 9 points for a hit in the innermost circle, 8 for the next circle, and so on to 1 point for the outermost. Total accuracy scores are for ten lunges obtained during test periods following bi-weekly periods of 45 minutes practice each. (Data from Ehrlich G., A method of constructing learning curves for a motor skill involving total body speed and accuracy,* J. appl. Psychol., *1943, 27, 494-503)*

were taken after the final period each week, from 87 young men who had no previous fencing experience. Scores were obtained by addition of points from 9 to 1, with the innermost circle counting 9, the next 8, etc., for ten lunges. The results of this learning are shown in Figure 8.19. Evidently, skill at this task can increase over many weeks. The perfect score for ten lunges would of course be 90.

The use of practice in the learning of motor skills has the effect of increasing the speed of performance and increasing the accuracy (or decreasing errors). These effects are illustrated in a study of the industrial task of screwing a ⁵⁄₁₆-inch screw into a tapped hole in a metal plate with a spiral ratchet screw driver. The learning of this task by five male operators is exhibited in Figure 8.20. These individuals practiced performing this operation for 200 times a day, for a total of 17 days. As the figure shows, the time taken to perform the operation progressively decreased. At the same time, the accuracy of the skill increased, as shown by the fact that the average number of times the screw driver slipped from the slot continued to grow smaller during the practice. The accuracy curve shows greater variation in this trend than does the time curve.

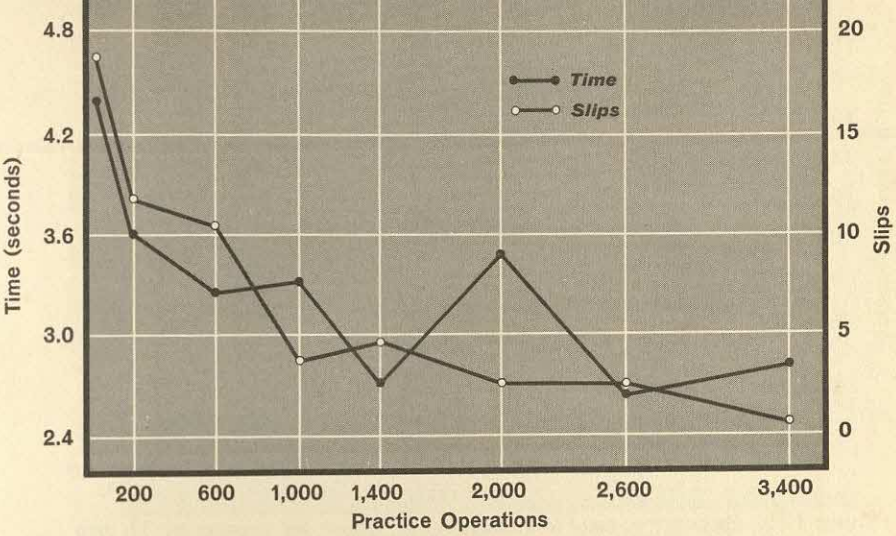


FIGURE 8.20. *Practice in screwing a* $\frac{5}{16}$*-inch screw into a metal plate with a ratchet screwdriver. The average performance of five male operators is shown, performing 200 operations per day. Increase in speed and accuracy (decreased frequency of slips of screwdriver from slot) of performance were measured. (Data from Barnes, R. M., and Amrine, H. T., The effect of practice on various elements used in screwdriver work,* J. appl. Psychol., *1942, 26, 197-209)*

Knowledge of Results

In practicing a motor skill, reinforcement usually takes the form of "feedback" to the learner concerning the degree of correctness (or error) of his responses. In most practice situations, the signal is quite obviously present. In making a fencing lunge, or positioning a button on a target, the learner can easily see the extent of his error and correct it in the next series of responses.

But in some learning situations, little knowledge of results is available. During World War II this was a persisitent problem in the training of aerial gunners. While a gunner was able to assess a hit on an opposing plane, he could not assess the extent of his error when he missed. On the rifle range, infantrymen may shoot at targets 200 yards away. It is impossible to assess one's error at this distance. If information about accuracy were not supplied, little or no improvement in marksmanship would occur with continued practice. Accordingly, visual signals indicating the part of the target hit are relayed back to the individual from the target area.

Even when the individual can assess the extent of his error visually, it has been found that more precise feedback can improve his performance. For example, on a task presented by the Rotary Pursuit device (see Figure 5.25b), the individual attempts to keep a stylus in contact with a moving target set in a revolving disc (60 RPM). While he can see if his stylus is

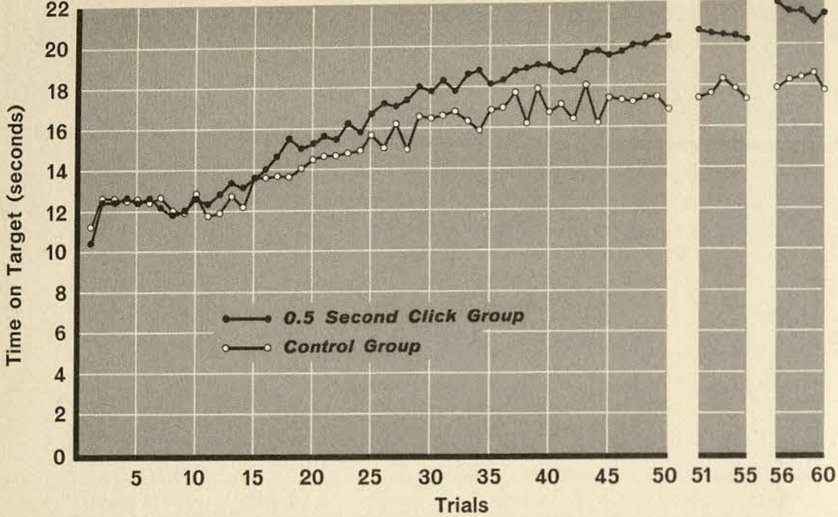


FIGURE 8.21. *Performance on the Rotary Pursuit device for a group of 33 men receiving an auditory click every .5 second of remaining continuously on target, and another group of 33 men who practiced without these clicks. The group receiving the additional knowledge of results is clearly superior. (After Reynolds, B., and Adams, J. A., Motor performance as a function of click reinforcement, J. exp.* Psychol., *1953, 45, 315-320)*

on or off, he can be provided additional feedback if he also hears a click when he has remained on target a certain short length of time. Figure 8.21 compares the performance of a group receiving such a click every half second the stylus remains on target, with that of a group not provided this signal. The advantage of the additional knowledge of results is clear. During a set of test trials (51-55), the click was not used with either group. Yet the group trained with the click maintained its superiority.

In situations where the effects of motor responses cannot be observed, no learning takes place. For example, in a study which required individuals to position a spot of light on a target in a two-hand control task, no improvement occurred in individuals who were not provided with knowledge of results. Furthermore, when the skill was learned under conditions in which knowledge of results was provided, removing this feedback led to a deterioration of the skill. These results are shown in Figure 8.22.

Sometimes a motor skill is acquired most rapidly when knowledge of the accuracy of responses is given in such a way that the internal (kinesthetic) cues are emphasized. This is presumably the purpose of emphasis on the "feel" of motor movements found in practice of athletic skills. A good example of the effectiveness of such emphasis is provided by a study of skill learning in an industrial task of disc-cutting from tungsten rods. This task is performed by means of a machine operated by a foot pedal, while the hands are engaged in holding the tungsten rod and operating the ejector mechanism. The successful operation of this machine de-

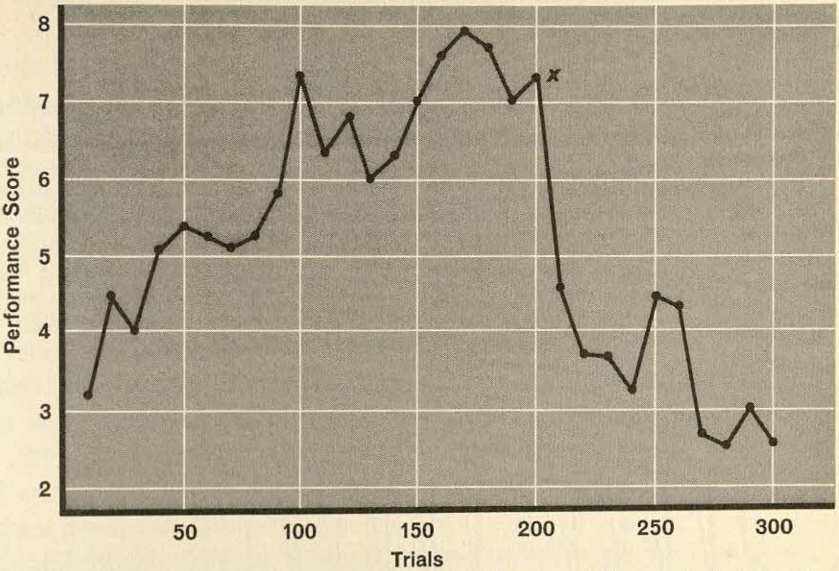


FIGURE 8.22. *The learning of a two-hand positioning skill, and its deterioration following removal of knowledge of results at point X. The task required the positioning of a spot of light on a target by manipulation of controls with the two hands. Scores express amount of error, in arbitrary units. (After Elwell, J. L., and Grindley, G. C., The effect of knowledge of results on learning and performance,* Brit. J. Psychol., *1938-39, 29, 39-54)*

pends critically on the speed, form, and pressure pattern of the sequence of responses required to operate the foot pedal. Improper operation results in damage to and breakage of the discs.

The end-product of this skill, in terms of number of good or bad discs produced, is observable by the individual who is learning the skill. However, errors in the pattern of actual motor responses are not immediately observable. What would happen if learners were given the opportunity to observe their pattern of foot movement directly and to compare it with a desirable pattern? In this study, this was done by making a direct tracing of this pattern on a moving tape, so that it was visible to the learners during practice. The changes in pattern of responses brought about by this kind of feedback are illustrated in Figure 8.23. After 239 hours of practice, the pattern of foot action was closely similar to that of highly experienced operators. Practice with this kind of feedback was found to be highly effective in improving disc production.

Discovering the Relevant Stimuli

As we have seen, most motor skills are to some degree externally controlled. The importance of external stimuli in learning the skill can be observed by introducing changes in the external stimuli which are connected to all or some part of the response-sequence. Much of the time spent in

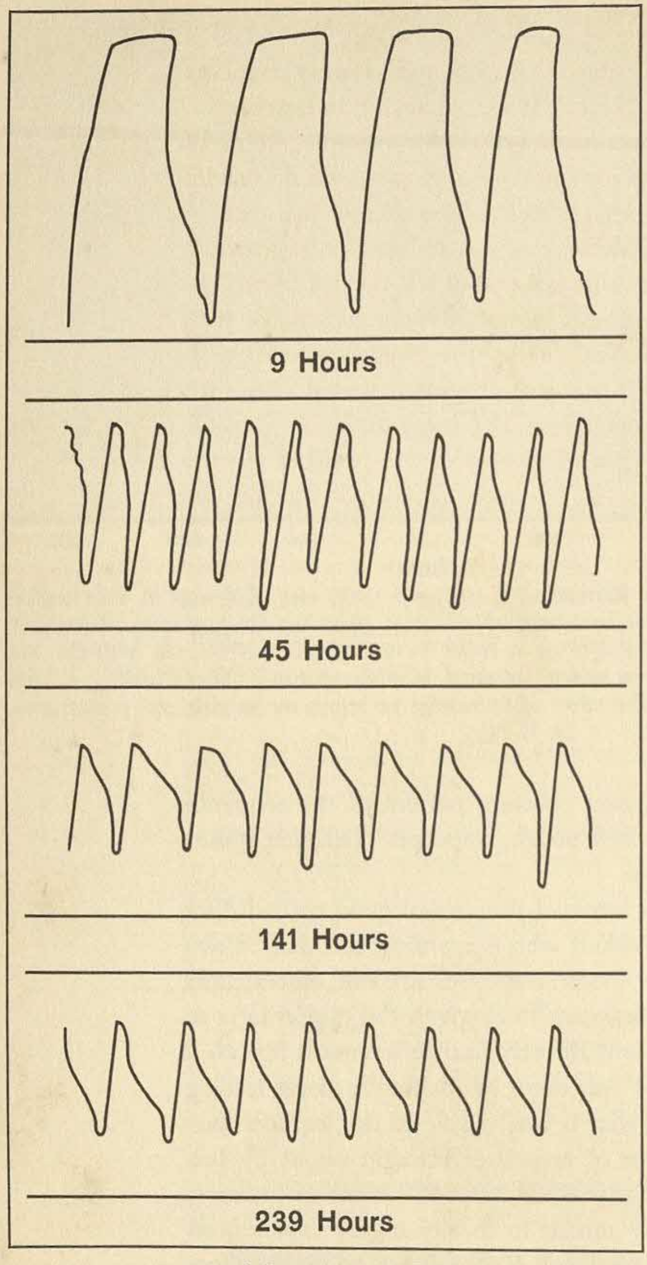


FIGURE 8.23. *Changes in response patterns on the foot pedal of a disc-cutting machine with continued practice. The learners were shown tracings of these patterns at intervals during practice, as well as illustrations of the correct pattern of foot movement. Sample patterns of learners are shown after 9, 45, 141, and 239 hours of practice. (From Lindahl, L. G., Movement analysis as an industrial training method, J. appl. Psychol., 1945, 29, 420-436)*

initial learning of skills is a trial-and-error process in which the response-sequence, after many false starts, becomes connected with the "correct" stimuli. From the many stimuli which constantly bombard the learner who is trying to acquire a skill, the ones which form habitual connections are often "discovered" through such trial and error. If we want to speed up this initial learning process, we may reduce the number of possible "false" stimuli, and thus reduce the time required for discovery of the correct ones. This is often called "guidance" of a skill.

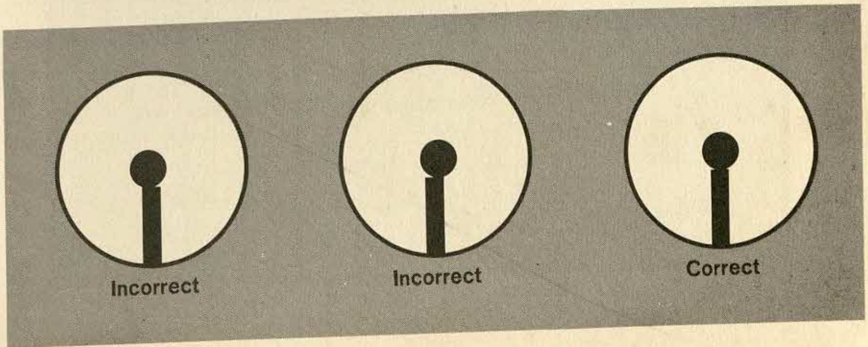
The guidance of initial learning of a skill may be done in various ways.

The situation in which the learner is placed can be, and often is, made as free as possible of stimuli which are "false." If we are trying to have an individual acquire skill in using a garden spading fork, for example, we make sure that the ground he practices on is typical of a garden; we do not let him practice on sand or on piles of rocks, with the false stimuli that each of these provides. Another way to guide learning is to direct the learner's attention to "correct" stimuli. For example, we may tell the learner to observe a particular angle which the prongs of the spading fork make with the ground, or the height of the fork blade above the ground before inserting it into the ground, and so on. Or we may provide a verbal rule, such as "To lift the fork with its load, place your left hand as far as possible down the handle." Each of these types of guidance accomplishes the important purpose of reducing the time of discovery of correct stimuli, and thus speeds up the total process of skill-learning.

In teaching the skill of rifle-firing at a target, instructors often place emphasis on the "correct sighting picture." By so doing, they call attention to the correct stimuli to be associated with the critical response of trigger-squeezing. Figure 8.24, for instance, is the kind of picture often used in instruction in rifle-firing. Such a sighting picture might be discovered after considerable practice in any case. But calling attention to it during initial learning has the effect of reducing the amount of trial-and-error required, and speeds up the learning of the skill.

A stimulus may be introduced into a skill-learning situation which is false, even though it may appear at first to aid the learning. Actually, when such a stimulus is accompanied by consistent reinforcement, the learner may come to use it as a "crutch." When this happens, he is in a sense learning the wrong skill. An example is provided by a study of flexible gunnery (air-to-air gunnery) skill. In this study, the individuals practiced tracking with a gun sight a moving target projected on a screen, similar to that pictured in Figure 13.9. Looking through the sight, they tracked the moving aircraft across the screen, and also framed it within a circle of dots. Their performance in this task was measured as amount of time-on-target; that is, the time during each practice trial that the projected aircraft was correctly tracked and framed.

FIGURE 8.24. *Correct and incorrect sighting pictures for rifle-firing.*



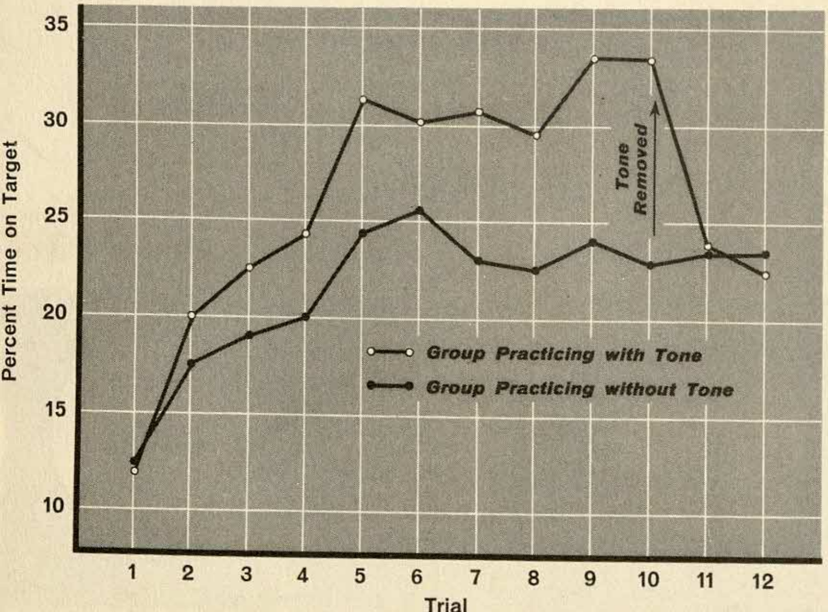
As a means of aiding learning, a buzzer tone was introduced which sounded whenever the learner was on target. It was reasoned that responses to the correct target picture might be effectively reinforced in this way. And indeed, as Figure 8.25 shows, the learning of groups of individuals with whom the tone was used was speeded up as compared with the learning of groups without the tone. However, this increase in speed of learning was deceptive, for when the tone was taken away, the performance of the group trained with it dropped immediately to the level of the group without it. Thus the tone was shown to be a false stimulus. The individuals who used it were learning the wrong skill; rather than learning the correct sighting picture, they were learning to "keep the tone on." Removing the tone showed the extent to which learning had occurred to this false stimulus.

Skill-learning can thus often be aided by techniques which reduce the time of discovery of correct stimuli. But caution is required in using these techniques, to insure that a false stimulus is not introduced. Such a stimulus, when accompanied by consistent reinforcement, can give the appearance of speeding the learning of a skill, when what is actually happening is that the false stimulus becomes a "crutch." When removed, it may be found to have been no help at all in learning the desired skill.

The Schedule of Practice in Motor-Skill Performance

Some important factors that influence the performance measured during the learning of a motor skill are the *time of continuous practice* and the

FIGURE 8.25. *The effect of the introduction of a tone as a "false" stimulus in learning flexible gunnery skill. The tone was removed at the point shown by the arrow. (From Morin, R. E., and Gagné, R. M., unpublished data)*



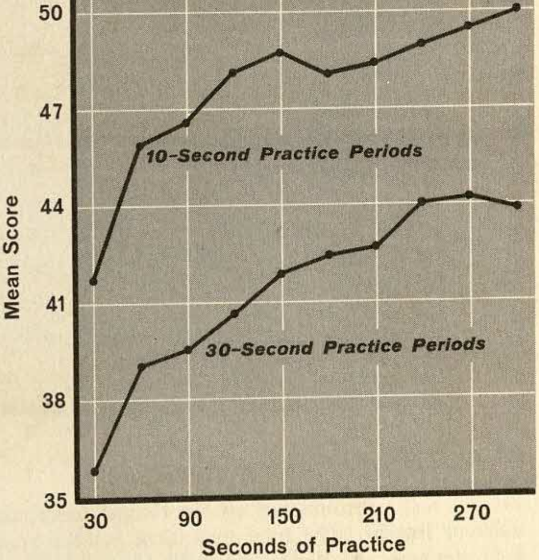


FIGURE 8.26. *Performance on the Minnesota Rate of Manipulation Test for trials of different length. The total time spent practicing and the time between trials were held constant. (After Kimble, G. A., and Bilodeau, E. A., Work and rest as variables in cyclical motor learning, J. exp. Psychol., 1949, 39, 150-157)*

interval between trials of practice. Schedules of practice that approach continuous responding with little or no rest are spoken of as *massed practice;* a condition providing more frequent pauses is called *distributed practice.*

Some typical findings on massed vs. distributed practice are shown in Figures 8.26 and 8.27. In the first of these studies, the skill to be learned involves manual dexterity—a set of small blocks must be picked up, turned over, and replaced as rapidly as possible (see Figure 5.27a). The individual's score is the number of blocks manipulated in a standard period of time. Two groups practiced for 300 seconds, but for one group this total interval was divided into 10-second trials, while the other group had 30-second trials. Rest periods between trials were held constant at 30 seconds for each group. As figure 8.26 shows, the shorter practice period leads to better performance.

What happens if we keep the periods of practice constant and vary only the rest interval between trials? This result is shown clearly in Figure 8.27. Practice on the Rotary Pursuit task was given a group of subjects, all of whom received 150 practice trials of 30 seconds' duration. However, different subgroups of these individuals practiced either continuously, or with rests of 3, 10, 20, or 30 seconds *between* trials. The longer the interval, the better was the performance. Moreover, rests of zero or 3 seconds produced markedly inferior performance, and differences among the groups in the final level of performance achieved is particularly striking.

Why is the spacing or massing of practice such an important factor in skill performance? If we were talking of long periods of heavy work, we should be inclined to think of the effects of muscular fatigue, and of changes in motivation associated with this. But in a study like the one just de-

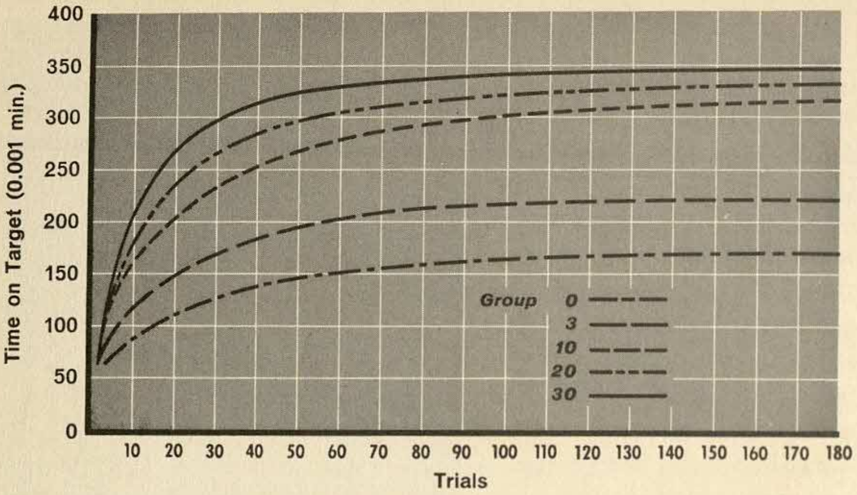


FIGURE 8.27. *Performance on the Rotary Pursuit device with rests between trials of different lengths. The total time spent practicing and the lengths of each trial were held constant. As the between-trial interval increased from zero to 30 seconds, the performance increased more rapidly and leveled out at a higher level. (After Adams,* J. A., *Psychomotor performance as a function of intertrial rest interval,* J. exp. Psychol., *1954,* 48, *131-133)*

scribed, the periods of practice and rest are relatively short, and we cannot suppose that muscular fatigue would differ significantly between conditions. Nevertheless, some factor related to the frequency of responding must be slowing up the process of skill improvement. It is generally believed that this factor must be the internal *inhibition* which we encountered in our description of simple conditioned responses. Each repetition of the sequence of responses being acquired in a skill does two things: It adds an increment of increased performance, and it contributes a smaller increment of *inhibition,* which tends to decrease performance, just as it does in experimental extinction. If we allow time to pass between responses, the inhibition will die away (as in spontaneous recovery) and we shall be able to begin each successive trial at a higher level of skill.

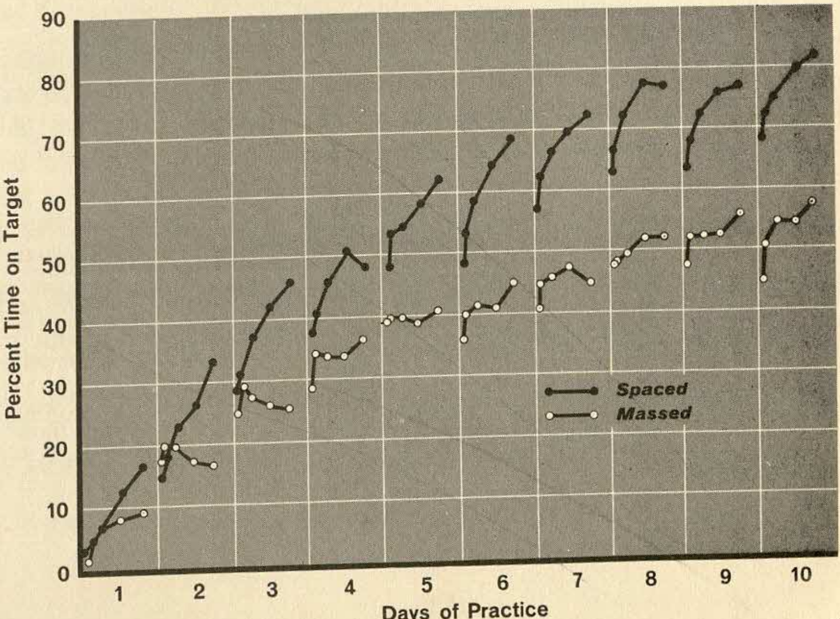
This effect is shown by the results of Figure 8.28, which are from a study of massed and spaced practice on a Rotary Pursuit task carried out over a 10-day period. The "massed" group had only a 5-10 seconds' rest between trials which were 50 seconds long, whereas the "spaced" group had a rest period of 65-70 seconds. Fifteen trials were given each day, and the points are plotted in terms of sets of 3 trials. Both groups show a decrement in performance between the last trial of a day and the first trial of the next day. In other words, there is a "warm-up" effect. The fact to be particularly noted, however, is the rapid increase of performance during each day of the *spaced* learning as contrasted with the *massed* learning. Theoretically, this is because the inhibition produced during a trial has greater opportunity to die away between the trials of spaced learning.

Is the level of skill permanently depressed by inhibition, or is this simply a transitory effect? Present evidence seems to show that the effect is a transitory one. If the group having massed practice is put on spaced practice and vice versa, the performance levels of the two groups rapidly reverse also. There is evidence from other experiments that the two groups in Figure 8.28 might exchange performance levels if the conditions were interchanged.[13] In other words, although inhibition affects *performance* during the learning of a skill, it does not primarily affect what is *learned.* If one "concentrates" the learning of a motor skill by continuous practice with very brief rest periods, we have no reason to believe that this is a particularly inefficient learning procedure, although its effects on immediate performance may be detrimental.

TRANSFER OF TRAINING IN MOTOR SKILLS

When a person has learned one motor skill, the learning of a new but similar one will usually be faster and easier. It is easier to learn to drive a motorcycle after one has ridden a bicycle, because the habits of turning and balancing have some similarity. People who have learned to swim in fresh

FIGURE 8.28. *Spaced and massed practice on a rotary pursuit task, 15 trials a day for 10 days. Data are plotted for time-on-target during each set of three trials. During each day's practice, the "spaced" group had 65-70 seconds' rest between trials 50 seconds long; the "massed" group had only 5-10 seconds' rest. (After Kimble, G. A., and Shatel, R. B., The relationship between two kinds of inhibition and the amount of practice, J. exp. Psychol., 1952, 44, 355-359; from Woodworth, R. S., and Schlosberg, H., Experimental psychology (Rev. Ed.). New York: Holt, 1954, p. 788)*



water readily swim in salt water, even though the buoyancy is quite different. A clarinet player learns to play a saxophone in a very short time compared with, say, a violinist. The procedure of training pilots in flight simulators assumes that relevant skills will transfer to performance in the actual aircraft.

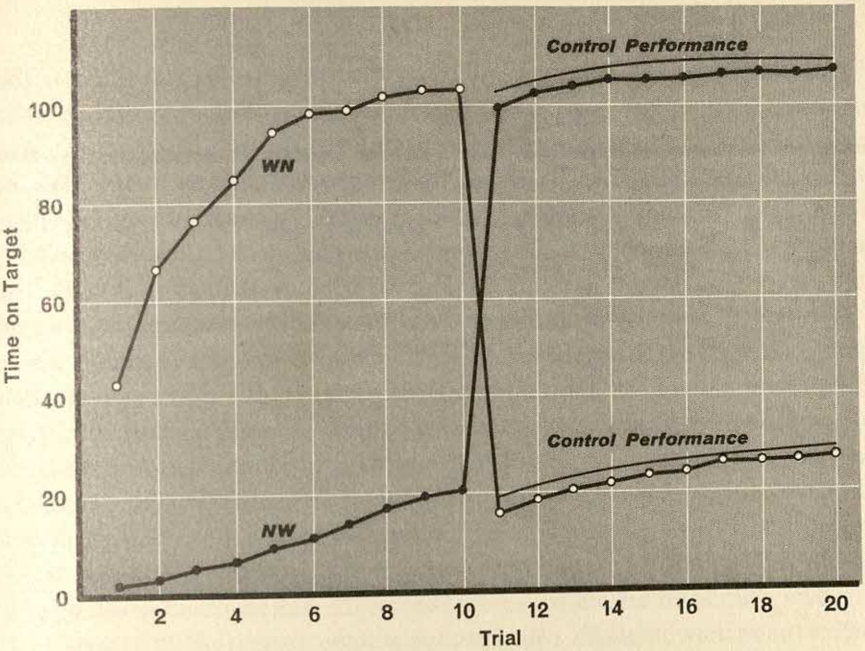
All of these examples attest to the widespread occurrence of *positive transfer* from a previously acquired motor skill to a new one. We are also aware that *negative transfer* occurs in motor skills. A person who changes from a standard-shift car to one with automatic transmission usually experiences some negative transfer effects, or *interference*. No one questions that these effects occur. But what conditions bring about positive transfer as opposed to negative? Under what conditions does an old skill facilitate or interfere with the learning of a new skill? We have discussed some of the general conditions of transfer of training in Chapter 6. Now we shall examine these phenomena more closely as they apply to motor skills.

Transfer and Similarity of Tasks

We learned in Chapter 6 that a primary condition for positive transfer is similarity of tasks. However, when we examine specific motor tasks more closely we find that it is not easy to state how similar two tasks really are. Task similarities may be described in various ways. Some similarities may be of greater importance to transfer than others. For example, one way to describe the similarity of tasks is in terms of their common ability requirements. If performance on two tasks involves *spatial orientation* we would expect positive transfer. Thus, a skilled navigator would be expected to learn blueprint-reading faster than someone starting from scratch. Similarly, in motor skills, individuals who have operated equipment dependent on the ability of *control precision* may more easily learn to perform other tasks involving this ability.

More commonly, tasks have been analyzed in terms of the similarity of the stimuli they present and the responses they require. From this evidence, it is clear that *stimulus similarity* is the most dependable condition for the assurance of high positive transfer. This is, of course, what happens when we change from one make of car to another in which the controls operate the same way. Much of our everyday behavior involves making responses to similar stimuli, and this makes possible a great deal of efficiency. We press door bells, switches, and buzzers and we pull and twist other devices. Most of our routine movements readily transfer to tasks having similar external stimuli.

But since internal (kinesthetic) stimuli are also involved in motor skills, the effect of these will be reflected in *similarity of responses*. When the



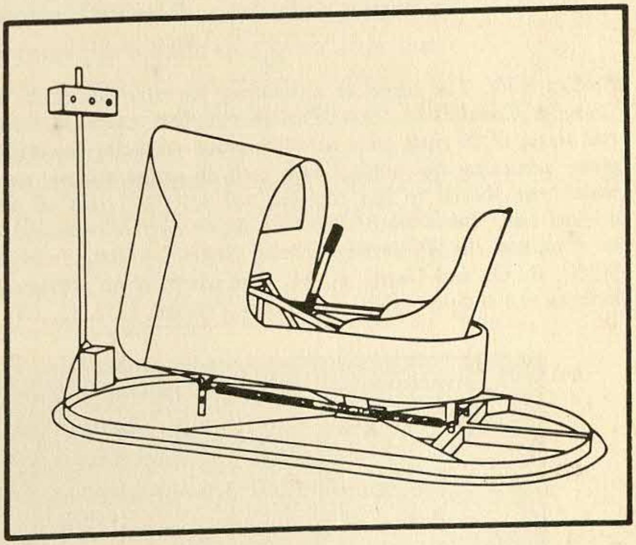


FIGURE 8.29. Above, scores for two groups of individuals on the Rudder Control Test with a shift in target size after the tenth practice trial. Group WN began practice with a target of 2⅞ inches, and continued on a target of ⅛ inch from trial 11 on. Group NW shifted from the narrow (⅛ inch) to the wide (2⅞ inch) target at the same point. The performances of both these groups during trials 11-20 indicate transfer of essentially 100 percent when compared with control performances on these targets. Right, a sketch of the basic Rudder Control Test. (Data from Gagné, R. M., and Bilodeau, E. A., The effects of target size variation on skill acquisition. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1954, Research Bulletin AFPTRC-TR-54-5)

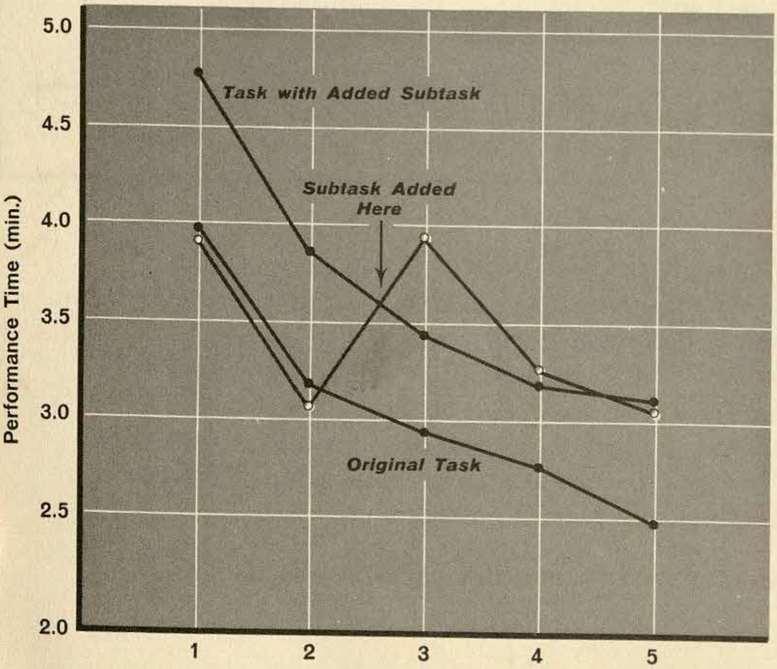
old and new skills are similar in the sense that their responses resemble each other, the evidence shows that increasing similarity leads to increasing amounts of positive transfer. For example, one study varied *precision of responses* between old and new skills, both provided by the Rudder Control test, a test used by the Air Force in air crew selection during World War II (see Figure 8.29). The task is one of keeping an unstable cockpit, in which the individual is seated, pointed at a target. One group of individuals was trained to keep the cockpit lined up with a target which was

2⅞ inches in width, while another group practiced the skill of aligning the cockpit with a target only ⅛ inch wide. After ten trials of practice, the group trained on the wide-target skill was shifted to the narrow-target skill and vice versa. As shown in Figure 8.29, the positive transfer was close to 100 percent for both of the new skills. Presumably, more extreme changes in required precision would have reduced the positive transfer below this amount.

Another way in which old and new skills may be similar is in sharing habits. In such cases, one of the skills may simply require a greater *number of habits* in sequence than the other. The difference in driving a car with a conventional gear shift and a car without one is largely of this sort. The conventional-shift car requires specific subskills of clutching and gear shifting which are simply *additional* to the many subskills common to the driving of both types of automobile. Consequently, the two total skills are highly similar, and high amounts of positive transfer occur between them.

The shift from an old to a new skill which has identical subskills plus one or more new subskills often produces some degree of *interference.* If a person shifts from a car with automatic transmission to one with a gear

FIGURE 8.30. *The effects of introducing an extra subtask in learning of the Complex Coordination Test. Performance-time scores are shown for 5 practice stages of 26 trials each, for (1) a group practicing the original task; (2) a group practicing the original task with an added subtask; and (3) a group which was shifted to the complex task after 52 trials of practice on the original task. Interference effects are shown by the increase in time required to complete the 26 settings during Stage 3. (Data from Baker, K. E., Wylie, R. C., and Gagné, R. M., The effects of an interfering task on the learning of a complex motor skill,* J. exp. Psychol., *1951, 41, 1-9)*



shift, the new performance may show some evidences of interference for a few trials; that is, it may temporarily be worse than would be expected even in a novice driver. But this is not truly negative transfer, because it can readily be shown that mastery of the new skill is achieved in fewer trials as a result of having learned the old skill.

Interference effects, along with positive transfer, were demonstrated in a study using the Complex Coordination Test (Figure 8.1) which requires individuals to match pairs of red and green lights by means of stick and rudder movements. To this task was added an additional task of positioning an extra gear-shift lever mounted at the left of the seat in which the individual sat. In response to an additional red or green light, the subject was required to push this extra lever into the correct position whenever he received instructions through headphones such as "green forward" or "red back." This extra subtask was obviously designed to be somewhat confusing to the individual who was engaged in practicing the main task of the Complex Coordination Test. The extra subtask was introduced after 2 stages of practice (26 trials each) on the original task. Figure 8.30 shows results.

Two things should be noted particularly about these results. First, the interference effects are transitory, and generally tend to disappear after one block of 26 trials. Second, despite the occurrence of interference when the extra task is initially introduced, there is positive transfer. Practice on the "old" Complex Coordination task without the extra gear-shift task made possible the learning of the "new" task which included the extra subtask in fewer trials. For instance, note that the group which practiced the total skill (task with added subtask) from the beginning required four learning stages to attain a time score of 3.2 minutes. But the group which had 52 trials on the "old" task required only two learning stages to reach approximately this score on the "new" task. For this group, the amount of positive transfer was about 50 percent.

Transfer between Tasks Involving Different Body Members

Positive transfer also occurs when similar responses are required in the old and new tasks, but by different body members, such as the right and left hands, or the hand and foot. For example, positive transfer is the universal finding in studies which require individuals to learn to trace a star pattern by looking in a mirror, and then to perform the same task with the other hand, or with the foot. This result can be no more than partially explained on the basis of similarity of external stimuli. Other studies have shown greatest positive transfer to occur between tasks having movements which are bilaterally symmetrical (and therefore opposite) for the left and right hands. Furthermore, there are striking resemblances between "hand-writing" of the preferred hand and the preferred foot, even when the individual is blindfolded. For these reasons, when we say that positive transfer depends on the similarity of responses, we are referring to those instances in which the tasks utilize the same muscle groups. When different limbs or sets of muscles are involved, transfer between tasks must be determined by some common events in the central nervous system.

The Occurrence of Zero and Negative Transfer

The transfer of training from one motor task to another may be zero, and often is. It would be a mistake to assume that because *similarity* is a prime condition for *positive* transfer, *dissimilarity* necessarily means that the transfer will be negative. In the usual meaning of the term, *dissimilarity* is most likely to result in *zero transfer* between motor tasks. Although there have been few formal studies of the conditions of zero transfer in motor skills, the fact that positive transfer drops off markedly with increasing dissimilarity of responses leaves little doubt of the validity of this principle. One does not expect transfer, either positive or negative, to occur between the performance of hammering nails and the performances of hitting a baseball, diving, or knitting.

Negative transfer occurs when the responses in old and new tasks are not simply dissimilar, but *reversed* with respect to their stimuli. Essentially, the basic condition may be diagrammed as follows:

Old Task: S_1——R_1
S_2——R_2

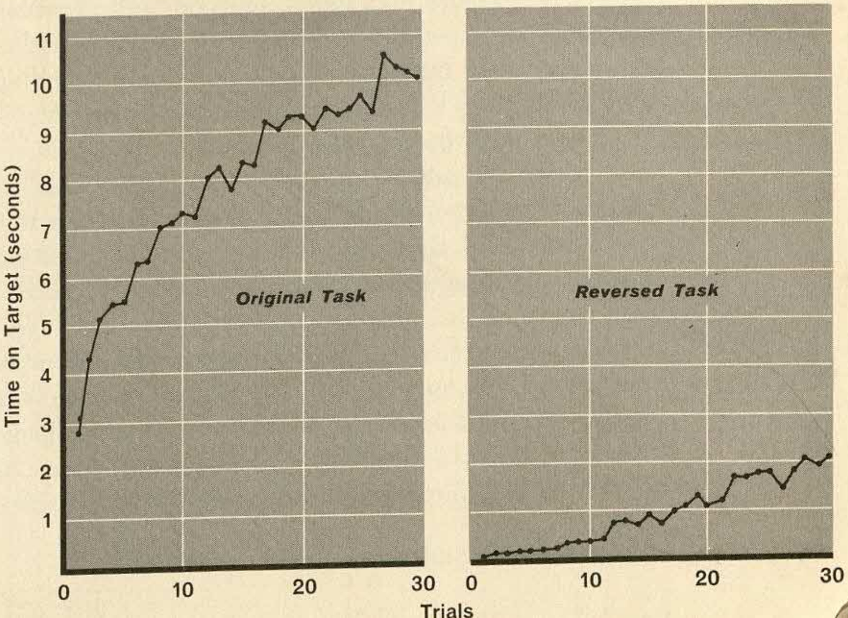
New Task: S_1——R_2
S_2——R_1

The stimuli S_1 which are associated with R_1 in the old task become attached in the new task to R_2, *while at the same time* the stimuli S_2 which were associated with R_2 in the old task become connected to R_1 in the new task. It is essential for negative transfer that both these changes occur in the new task. If only one occurs (a kind of partial reversal) we simply have an example of an added response in the new task, and this condition, as we have seen, will result in some interference but not necessarily negative transfer.

There are few common examples of genuine negative transfer, in which the interference is so great between two tasks that the learning of the "new" task is slowed down more than it would be if the individual had not learned the "old" task. But we can imagine situations in which negative transfer would take place. For example, if all the keys on a typewriter were to be shifted at random to new positions, it would doubtless be possible to measure negative transfer in typists who had practiced with the standard keyboard.

The dependence of negative transfer on reversal of S-R relationships was demonstrated in a study which undertook to insure such total reversal. The task was one in which individuals practiced keeping a spot of light on an irregularly moving target by manipulating two handles, one with each hand. In the initial task, one handle controlled the clockwise movement of the spot, while the other controlled the vertical movement of the spot. In the second (new) task, the same responses were made to determine opposite movements of the spot, so that the responses which were previously learned to "clockwise-down" now became connected with "counterclockwise-up." After having practiced the original task during ten trials a day for three days, the experimental subjects then were switched to the "reversed" task for the same number of trials for three days. Figure 8.31 shows the results of this study. As can be seen, performance on the second task was very poor. The individuals who had practice on the original task performed less well than did subjects who had had no practice at all (this performance is not shown directly in the figure but may be estimated from the performance on the original task). Thus these results provide an example of transfer which is truly negative.

FIGURE 8.31. *Decreased performance in a second task resulting from reversal on S-R relationships practiced in a first task. Performance on the second task is so poor relative to initial performance on the first task that negative transfer can be presumed. Practice was given on the first task during 30 trials, 10 trials a day for 3 days. The task required the learner to keep a spot, controlled by two handles, on a moving target. Following reversal, the new task was also practiced for 3 days, 10 trials per day. (After Lewis, D., and Shephard, A. H., Devices for studying associative interference in psychomotor performance: IV. The turret pursuit apparatus,* J. Psychol., *1950, 29, 173-182)*



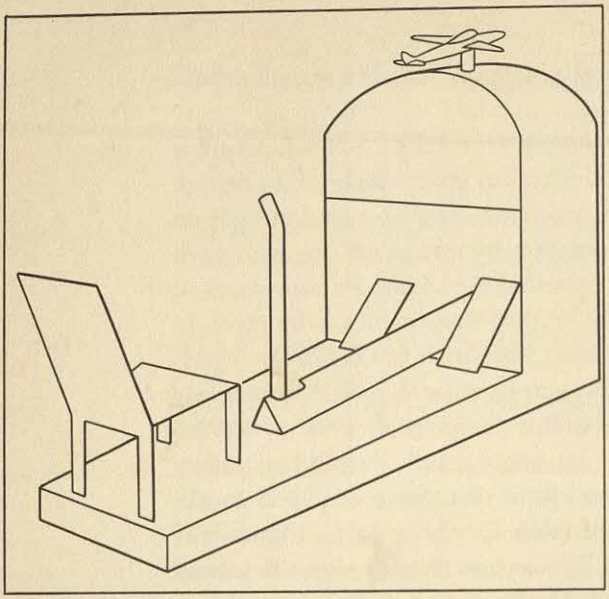


FIGURE 8.32. *The Plane Control Test. The operator tries to keep the model plane "flying" straight and level, compensating for deviations in pitch, roll, and turn. He does this by coordinated movements of the stick and rudder controls. (From Fleishman, E. A., Dimensional analysis of movement reactions,* J. exp. Psychol., *1958, 55, 438-453)*

RETENTION OF MOTOR SKILLS

We have already pointed out that most motor skills, once learned, are better retained than other types of skills. Once we learn to skate, typewrite, ride a bicycle, or drive a car, we can perform these skills even after many years without practice. As indicated in Chapter 6, this may be due to the fact that motor skills are enormously *overlearned*. This is especially true when they are compared to verbal sequences like foreign vocabulary lists, which are forgotten quickly in the absence of practice.

A recent series of studies obtained data on retention of a motor skill for intervals without practice of 24 hours, 1 month, 6 months, 1 year, and 2 years. Original practice was on the Plane Control device (Figure 8.32), and practice continued for 8 hours (32 fifteen-minute periods) for each subject. As Figure 8.33 shows, only the groups without practice for one and two years showed decrements in performance, and these were slight. All groups regained their previous level of performance within two hours, although the group with the 2-year interval took longest.

These investigations also measured retention in a group trained only one hour in the original practice period, rather than eight. A greater proportion of proficiency was lost by these individuals for similar intervals of no practice, but there was still a remarkably high amount of retention. Again, all of the groups attained their original levels of performance in less than two hours.

Thus it appears that complex motor skills are retained at a high level over periods of no practice, and that no-practice intervals of up to six months may produce no measurable loss. Although longer intervals produce some loss, this can be overcome with brief practice. A greater proportion of skill is lost when smaller amounts of initial practice have been given.

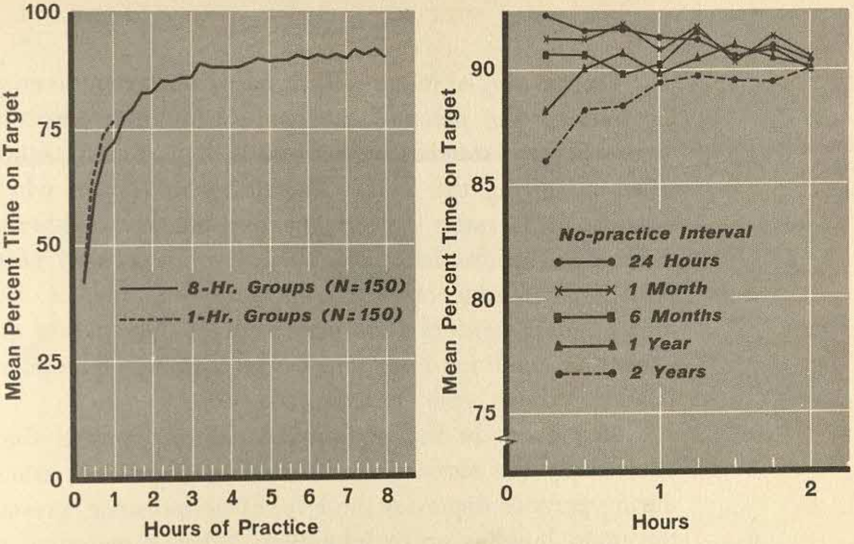


FIGURE 8.33. *Retention of a complex motor skill up to 2 years without practice. Performance on the Plane Control Test for 150 subjects during original learning (8 hours) is shown at the left. These subjects were divided into 5 groups which went without practice for intervals from 24 hours to 2 years. The performance curves of these 5 groups after intervals of no practice is shown at the right. (After Ammons, R. B., et al., Long term retention of perceptual motor skills,* J. exp. Psychol., *1958, 55, 318-328)*

SUMMARY

An individual's *basic motor abilities* are important determiners of performance on specific motor tasks. However, high *levels of proficiency* on *specific skills* also depend on how well different individuals profit from their experience with particular tasks. This chapter has reviewed the conditions which lead to effective performance in motor tasks.

The *response mechanism,* on which motor skills depend, is composed of *central synapses, motor nerves, neuro-muscular junctions,* and *muscles.* Its capacities may be described in terms of *speed, force,* and *precision. Speed* of reaction varies with the sense organ receiving stimulation, with the intensity of the stimulus, and with the response required. It is influenced by central neural events including motivation, preparatory set, muscular tension, and factors related to age and sex.

Force capacity of the response system varies mainly with the muscle groups involved. But even for particular muscles, direction and extent of movement have important effects on the force of movement. *Response precision* is reflected in man's steadiness, muscular tremor, accuracy of positioning movements, and the control of continuous movements.

Motor skills are *sequences of responses* which are controlled by *external* or *internal* (*kinesthetic*) stimuli. Skills may be composed of discontinuous responses, or of continuously graded responses to stimuli. Most practical skills are of a mixed nature with respect to these variables.

The learning of motor skills is based upon reinforced practice. Increasing *frequency of practice* may produce improvement over long periods of time, when the standard of mastery is high. Reinforcement is usually provided by giving the learner *knowledge of results,* which appears to be essential for learning. In certain skills, such knowledge can be obtained by direct observation. In others, special measures may need to be taken to provide knowledge of actual responses in terms of movement patterns rather than in terms of performance effects. *Discovering the relevant stimuli* is another condition important to the learning of motor skills. It is facilitated by various types of guidance.

Differences in the performance of motor skills during learning are affected by the *massing* or *distributing* of practice trials. Massing trials during practice depresses the level of performance, presumably because of the rapid building-up of *inhibition.* When a period of rest is allowed to intervene, however, the performance recovers. Massing of practice apparently exerts its effect on immediate performance, rather than on the learning process itself.

Transfer of training is a phenomenon of considerable significance in the learning and in the use of motor skills. High *positive transfer* depends on the *similarity of stimuli* and *responses* in the "old" and "new" tasks. *Negative transfer* occurs when the responses of the second task are *reversed* in relation to the same stimuli occurring in both tasks. The addition of partially conflicting responses in a second task may lead to interference from practice on a first task, but this effect is transitory. *Dissimilarity* of two motor tasks results in *zero transfer* between them.

Motor skills are *retained* over long periods of no practice, with relatively little loss in proficiency.

READING REFERENCES

McGeoch, J. A., and Irion, A. L., *Psychology of human learning* (Rev. Ed.). New York: Longmans, 1952. A summary of principles of learning and transfer of training derived from experimental studies.

Osgood, C. E., *Method and theory in experimental psychology.* New York: Oxford, 1953. A textbook describing experiments on learning and transfer of training and the theories on which they are based.

Welford, A. T., *Ageing and human skill.* London: Oxford, 1958. A description of changes of skill with age, containing much information about motor skills.

Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954. A basic text including experimental results on reaction-time, learning and transfer in motor skills.

9

CONCEPTS AND THINKING

Man's use of concepts is the most important part of his verbal behavior. Almost every hour of his waking day, a person uses concepts. He does this by initiating internal responses which then function as stimuli for the control of behavior in a wide variety of situations. Concepts make it possible for the individual to generalize his past experience and to apply previously acquired knowledge in novel ways. When concepts are used as symbols in communication, the individual is able to control other people's behavior as well as his own. Concepts are also used in thinking, and you will become acquainted in this chapter particularly with the type of thinking that is directed toward a goal; that is, with problem-solving.

One of the most versatile forms of man's behavior is *concept-using.* We saw in Chapter 3 that the possession of concepts by human beings makes possible a tremendous broadening of the scope and complexity of their behavior. Men are able to *generalize* their previous experiences by using concepts.

In this chapter, we shall be dealing with various forms of conceptual behavior. We shall see that concepts make it possible for an individual to respond appropriately to a situation in which he has never been before. For example, if a person is to visit Paris for the first time, his past experience can be generalized by our telling him, "The subway is called le Métro." We are able to control his subsequent behavior by such a statement, for we can be fairly sure that when he gets to Paris, he will control *his own* behavior by recalling "Métro" when he is looking for a subway. Furthermore, he will be able now to affect still another person's behavior in a similar way, by "passing on his knowledge" to a friend who may not have acquired this concept.

But these are only the simplest of activities which can be set off by concepts. Our friend will be able, by looking at a map of the Métro, to *plan* a trip to various parts of the city, perhaps requiring changes of trains at several stops. He can do this because he is able to carry in his head a sequence of concepts referring to directions and transfer points. Or again, he may have to *think out* a problem that requires him to use concepts referring to the consequences of his behavior. For example, he may have to decide which of several alternative routes will get him to a given point in the city most rapidly. Finally, he may pose other problems for himself by means of concepts. Perhaps he will wonder what circumstances led to the building of the Métro, or how the trains are powered, or what effect the system has had on the business and cultural life of the city.

Thus concepts underlie a great variety of forms of behavior ranging from simple control of habitual acts to the rich interplay of "thoughts" and "ideas" in intellectual speculation, as well as to the more rigorous forms of scientific problem-solving. In this chapter, we shall consider first the simplest of these functions, the *control* of one's own and other people's behavior by means of the *generalizing* property of concepts. We shall describe some facts about how concepts come to function as internally aroused signals which make possible effective behavior in entirely new situations. Finally, we shall be concerned with the most important function concepts can have—their use in *thinking* and *problem-solving.*

CONCEPTS AND SYMBOLS

When functioning as concepts, verbal responses become signals that arouse a variety of other habits and skills (see Figure 3.5). As we have pointed out previously, the habitual responses over which the concept exerts control are in fact what is meant by the *meaning* of a concept. The most common meaning of the concept "pencil," for example, is the activity of making marks on paper; that of "stairs," the responses involved in ascending and descending. But even such common objects have more meanings than one, as we can readily discover by asking people what they think of when they see a pencil or a set of stairs. And a concept like "the United States" may arouse a whole complex of other concepts which pertain to residing in a particular town and state, traveling throughout the country, voting, saluting the flag, paying taxes, singing the national anthem, and many others.

Although it is perfectly possible to imagine a set of concepts which would have meaning to only one individual, the fact is that the meanings of concepts arise within situations involving other people. Were an individual to grow up from birth on a desert island devoid of human company, probably the facts of neural organization would insure the development of a private store of concepts serving the function, for the individual, of controlling his own behavior. But the typical human infant grows up in contact with other individuals from birth onward; in fact he could not survive without such social contact. Thus, he acquires verbal responses which function as concepts in determining his behavior, in much the same way as they determine his parents' or other people's behavior. Although all of us may have a certain number of "private" concepts, even ones that we cannot put into words, we typically acquire concepts as verbal responses which are learned in the process of communicating with other people.

An external stimulus which arouses the same concepts in two or more individuals is called a symbol. In other words, symbols are used to *convey meaning* from one individual to another. Any kind of stimulus may serve as a symbol provided it can be shown to communicate meaning, that is, to arouse a concept. Thus a yellow sign of octagonal shape at the edge of a highway may be a symbol for the concepts involved in stopping an automobile at a through street, whether or not the word "Stop" is legible. Or a gesture with arm or hand may readily convey meaning from one individual to another. Even the contraction of facial muscles into a look or frown may be the stimulus for the arousal of concepts in another individual.

The commonest kinds of symbols, however, are words (and numerals) themselves, whether printed, written, or spoken. Although any stimulus may function as a symbol, concepts themselves, in their externally expressed form, usually become the symbols which communicate meaning to other people. And because human beings are distinctly social animals, their concepts are in fact acquired as a result of being used as symbols by parents and other people.

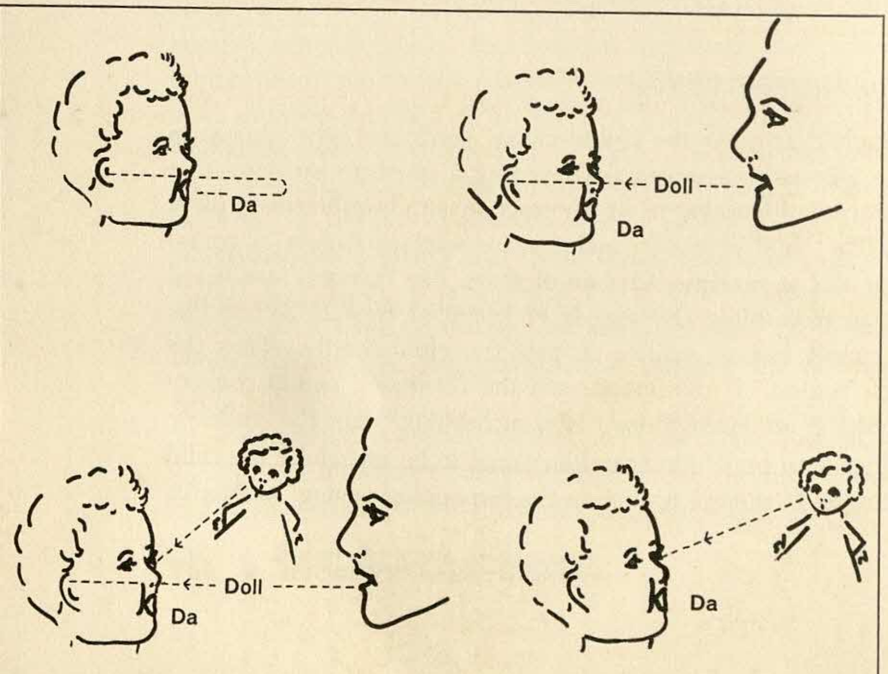
Learning of Symbols by Children

The young child acquires the ability to say words and brief phrases in much the same way as he acquires skill in using a spoon to eat with—that is, through a process of learning in which practice with reinforcement plays its usual role. The child originally makes a tremendous variety of verbal sounds, more or less at random. Certain of these, like "ma-ma," are heard by the parent as resembling the sounds of accepted speech. When this happens, the parent beams, smiles, or pats the child fondly. Thus the verbal response "ma-ma" is reinforced, and the functional neural connections that underlie it are strengthened. On succeeding trials, the tendency of "ma-ma" rather than some other random sound to be spoken by the child is greatly increased. It is not long before the response of saying "ma-ma" is attached by a firm habitual connection to such a stimulus as the parent's own verbalization, "Say mama!"

A representation of the steps in the acquisition of a simple language habit by a child is shown in Figure 9.1. In step A, the child vocalizes the syllable "da," as one among many. The sound of this syllable also evokes the further motor response of saying "da" (so that the child, as is well known, tends to say "da-da-da-da-"). In step B, a parent says the word *doll,* which is sufficiently like *da* that it too evokes the response *da* in the child. Such an event is likely to be most pleasing to the parent. Step C is one in which the external stimulus of a real doll accompanies the stimulus "doll" spoken by the parent, and is again followed by the response "da" of the child. After a few such trials, there is an easy progression to step D, in which the doll by itself elicits the spoken "da" by the child. This response of "da" gradually becomes refined into the spoken word "doll."

At this point, the word "doll" can be assumed to function as a symbol for the parent only. When spoken by the child, it can communicate his desires to the parent. As a concept, it controls the parent's activity when he fetches or retrieves the doll for the child. At some stage of development, probably at about age three, the word "doll" also becomes a symbol for the child as well, and is able to arouse in him habits of fetching the doll which function similarly to those of his parents. At such a stage, the true symbolic character of the word becomes established, as does its function in communication.

FIGURE 9.1. *Steps in the learning of a simple language habit in the child. (After Allport, F. H.,* Social psychology. *Boston: Houghton Mifflin, 1924)*



Symbol Sequences

The meaning of concepts as symbols, however, is not fully accounted for in terms of single words. Language is spoken and written in sets of connected phrases and sentences. As a result, a single word conveys meaning that is based partly on the words which have preceded it in sequence. We habitually respond to "words in context," more often than we do to single words.

The way in which sequences of symbols determine meaning has been shown in a study in which people were asked to predict sequences by using given words in sentences. The resulting sequences can be compared with

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TABLE 9.1

MEANING AS CONVEYED BY SEQUENCES OF WORDS PREDICTED BY DIFFERENT INDIVIDUALS IN SUCCESSION

ZERO ORDER (RANDOM)

betwixt trumpeter pebbly complication vigorous tipple careen obscure attractive consequence expedition pane unpunished prominence chest sweetly basin awoke photographer ungrateful

FIRST ORDER (APPROXIMATING FREQUENCY OF USAGE)

tea realizing most so the together home and for were wanted to concert I posted he her it the walked

SECOND ORDER

sun was nice dormitory is I like chocolate cake but I think that book is he wants to school there

THIRD ORDER

family was large dark animal came roaring down the middle of my friends love books passionately every kiss is fine

FOURTH ORDER

went to the movies with a man I used to go toward Harvard Square in Cambridge is mad fun for

FIFTH ORDER

road in the country was insane especially in dreary rooms where they have some books to buy for studying Greek

SEVENTH ORDER

easy if you know how to crochet you can make a simple scarf if they knew the color that it

PROSE

more attention has been paid to diet but mostly in relation to disease and to the growth of young children

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(From Miller, G. A., and Selfridge, J. A., Verbal context and the recall of meaningful material, *Amer. J. Psychol.*, 1950, *63*, 176-185.)

"artificial" sequences composed of randomly selected words, as well as with regular prose.

In this study, the results of which are shown in Table 9.1, a *zero order* sequence was constructed, for comparison purposes, by listing twenty English words at random. In addition, a *first order* sequence was constructed to contain twenty words that occur with approximately the frequency they have in English prose. To obtain the *second order* sequence, the word *sun* was entered in the sequence and then presented to an individual, and he was asked to use it in a sentence. Then, the word he used directly after *sun,* namely *was,* was in turn entered in the sequence and given to another person to use in a sentence. This method was repeated in a number of individuals, and the 20-word sequence shown in the table resulted. Presumably, each individual was providing a word which was highly probable as the next in sequence. The increase in meaning between first and second order sequences is apparent.

To obtain *third order* sequences, each individual was given two words that had been entered in the sequence and asked to complete a sentence. That is, one person was presented with the words "family was," and his sentence contained the following word *large.* It was entered in the sequence. The next individual was given the words *was large,* and the next word in his sentence turned out to be *dark. Fourth order* sequences were obtained by beginning with three words; *fifth order* with four words, and so on. Obviously there is an increase in meaningfulness of the resulting sequences, and an increasing tendency to approach the kind of meaning conveyed by the symbol sequences of ordinary prose.

GENERALIZING WITH CONCEPTS

Concepts, used as symbols, convey meaning to the individual and to other people. They also make possible the generalizing of behavior to many situations which differ widely from each other in physical stimuli. Different types of concepts begin to have this generalizing function at different times during the course of normal human development. Basically, this fact reflects the development of greater neural capacities, although it must also be influenced by factors arising from the accidental experience of any one individual. Class concepts expressed as common nouns apparently begin first to function as concepts, whereas rules and abstractions require more advanced neural development.

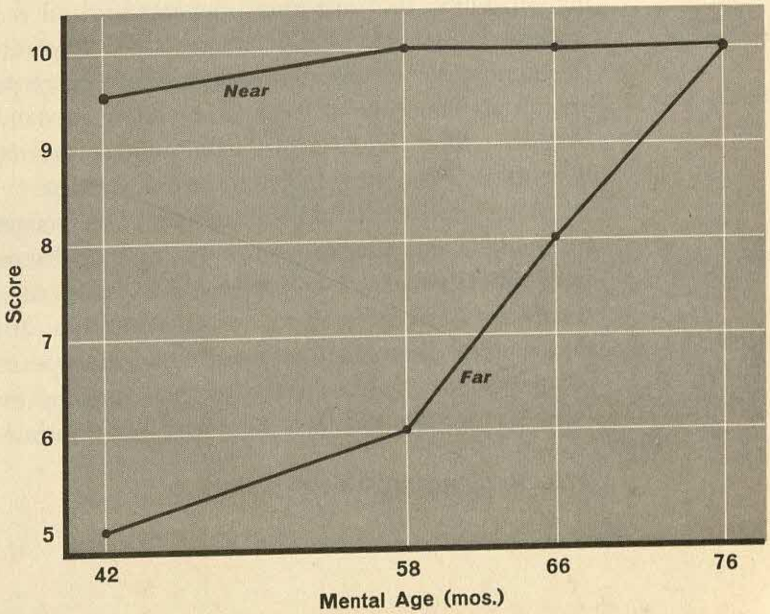
A study of the functioning of the concepts "big" and "small" in young children illustrates how generalizing occurs. The children in this study ranged in age from 30 to 70 months, and in Mental Age (as given by the

Stanford-Binet Test) from 36 to 83 months. Each child learned to choose the smaller of two white squares arranged on a panel. By choosing the smaller square, the child could open the lid of a box, to which the square was attached, and obtain a toy. The larger square was attached to a lid that would not open. For this learning session, the squares used had areas of 37.8 and 68.0 square inches (a ratio of 1:1.8).

Now the question was asked, can the child generalize the learned habit of reaching for the *smaller* square when the absolute size of the squares is changed? And does it matter how different the two situations are? Specifically, are there differences in the generalizing the child does in "near transposition," when the absolute sizes of the squares are not very different from those of the training series, and in "far transposition," when the absolute sizes are made very different? For the "near transposition" test, the smaller square was 21.0 square inches, the larger 37.8 inches. In contrast, in the "far transposition" test, the two squares were both quite different from those of the training series, and were only 2.0 and 3.6 square inches.

The results are shown in Figure 9.2. Little difference in performance was found in the "near transposition" test for the various mental-age groups. On the other hand, very marked differences were found for the "far transposition" test. Records of verbalizations of the children indicated increas-

FIGURE 9.2. *The performance of children of different mental ages on "near" and "far" transposition tests. Scores represent medians for 7 children at median MA 42 months, 11 at 58 months, 12 at 66 months, and 14 at 76 months. Near transposition is performed successfully even by very young children. Far transposition, on the other hand, shows a marked increase with age. (After Kuenne, M. R., Experimental investigation of the relation of language to transposition behavior in young children, J. exp. Psychol., 1946, 36, 471-490)*



ing use of the class concepts "little" and "big" with increased mental age.

This experiment shows that there is no evidence of growth in the capacity for *stimulus generalization* (see Chapter 6) between the ages of three and seven. "Near transposition" depends on this fundamental process which can readily be demonstrated in animals lower than human beings. In contrast, "far transposition" depends for its occurrence on control of behavior by *concepts*. Typically, the three-year-old is unable to control his behavior by saying to himself, "It's in the smaller one," whereas the six-year-old almost always does use such concepts. For this reason, transfer was very limited in the three-year-olds in this study, but extensive in the older children. Somewhere between these ages, verbal responses begin to have their truly conceptual functions of generalizing. Of course, the communication function of these concepts as symbols may also be demonstrated at this time, as would be the case if an adult said, "Choose the smaller one."

Thus the use of concepts permits human behavior to transcend the limitations of specific habits and skills tied to more or less specific stimulus-situations. The use of concepts and sequences of concepts in generalizing is a common occurrence in certain performances which pervade our daily lives. One of these is *speaking*, by which we mean the kind of performance shown in conversing, in making an extemporaneous speech, in dictating a letter, and similar activities in which the sequence of words employed is determined by the meaning we wish to convey. We distinguish this sort of speaking from the simpler activities of word enunciation or recitation, which can be accounted for as stored habits or verbal sequences. A second kind of performance which displays the use of concepts, and is closely related to the first, is *writing*. Again, we distinguish the kinds of performance found in composing a written letter, essay, or story, from the motor skills of penmanship and typing, as well as from the simple reproduction of previously learned word and number sequences. A third kind of performance is *reading*, in which the individual understands and reacts to printed words as concept sequences. Finally, there is the important activity of *arithmetic calculation*, by means of which human beings put number and number-operations concepts to work in a variety of daily chores such as making change, telling the time of day in another part of the country, estimating floor space, calculating income, and many others.

These conceptual skills have long been recognized as basic for successful living in our culture. It is not surprising, therefore, that they are essentially what is meant by "the three R's," which are generally agreed to constitute the basic subjects for formal education. It is these conceptual skills that mainly distinguish a formally educated person from a totally uneducated person. No doubt the original impetus to formal education arose from the recognition that these skills, in contrast to many other kinds of knowledge, are not readily "picked up" through experience, but must, instead, be learned in an organized manner.

THINKING

We now turn our attention to the most intricate kind of behavior based upon the use of concepts. This is *thinking*. We shall devote primary attention here to the goal-directed type of thinking called *problem-solving*. But first, we consider various other meanings the word *thinking* can have.

Types of Thinking

In its broadest sense, the word *thinking* is often applied to the entire set of functions which may be set in motion by concepts. As we all know from our own experience, an individual may be sitting quietly and exhibiting scarcely any visible activity, yet at the same time a very active and varied flow of concept sequences may be occurring.

IMAGINING. At an elementary level, the construction of concept sequences by the individual constitutes a type of thinking usually called *imagining*. Note that this function is not simply one of recall of concepts, in some random order or in an order in which they may have been learned originally. Instead, the activity is one of *generalization* or *transfer* of recalled concepts to new situations.

We may begin the process of imagining, for example, by saying to an individual, "Imagine yourself huddled over a small fire in an Arctic wasteland." Unless such an individual has actually been in such a situation, we are asking him to recall a set of appropriate concepts and to *generalize* them to this specific new situation. Or, the individual may himself begin the process of imagining, as in *daydreaming*, in which he may use his store of concepts to apply to a limitless variety of new situations. Such imagining may be elaborated into long and intricate sequences, like the daydreams of Walter Mitty.[1] Recalled models ("images") as well as verbal concepts, may occur as part of these imagined sequences, although images are not essential to the process of imagining.

REASONING. In its simplest meaning, *reasoning* is the generalization of concepts to a situation in which there is a specific response capable of being verified. Typically, there is a question which has a correct answer that the questioner either knows beforehand or can verify independently. As we have just seen in the previous sections, the transfer of concepts may be directed to such specific goals as spelling a word, reading or writing a sentence, or performing an exercise in arithmetic. Thus we expect an individual who has acquired the concept (rule) of multiplying 3 by 2 to be able to *reason out* the answer to any specific question such: "John has 2 apples. Fred has three times as many. How many apples has Fred?" This type of thinking is directed toward a more specific goal than imagining. Furthermore, it is subject to independent verification.

PROBLEM-SOLVING. Sometimes, the solution to a problem is "thought out" in a series of steps, each one of which requires a choice from among alternative concepts. This process is called *problem-solving;* and the choosing or "weighing" of alternative concepts is referred to as *judgment.* When we use "problem-solving" in this technical sense, we do not mean simply generalizing a recalled concept to a new situation, as in the example of reasoning in the previous paragraph (which is often referred to as "solving an arithmetic problem"). We have in mind rather a situation in which the individual must, in order to achieve a solution to a problem, *choose among alternative concepts.* In this sense, the question "What is three times as many as two apples?" does not require problem-solving in its technical meaning.

We can give some inkling of the basic nature of the process of choosing concepts (though not of the total process of problem-solving) by means of the following example. Suppose we ask an individual to fill in the blank of the sequence 2 4 __ 44. He must here choose from among alternative concepts, since the progression 2 4 __ may be completed by the number 6 (concept: adding 2); by the number 8 (concept: multiplying the preceding number by 2); by the number 16 (concept: squaring the preceding number); or by the number 12 (concept: subtracting 1 from the preceding number and multiplying by 4); among others. Similarly, when thinking is of the sort called problem-solving, we go beyond the stage of simple utilization of a concept. The process of judgment comes into the picture.

PROBLEM-SOLVING

An interesting description of problem-solving activity is provided by the psychologist John B. Watson. Since Watson was concerned with emphasizing the resemblance between problem-solving and the "trial-and-error" behavior of a rat in a maze, the example contains references to such things as the "starting point" and "cul-de-sac" (i.e., blind alley).

> A colleague of mine came on a visit to stay in an apartment in which I had rooms. In a passage leading from the shower bath was a peculiar piece of apparatus standing near a sink. The essential features were a curved shallow nickel pan about twelve inches wide by twenty inches long; at one end the pan had been bent in in the form of a half circle,

> while at the other end the side pieces did not extend for the full width. The pan was mounted on a stand adjustable in height. Furthermore the pan itself was attached to the stand by a ball and socket joint. My friend had never seen anything like it and asked me what in the world it was. I told him I was writing a paper on thinking and pleaded with him to think his problem out aloud. He entered into the experiment in the proper spirit. I shall not record all of his false starts and returns but I will sketch a few of them. "The thing looks a little like an invalid's table, but it is not heavy, the pan is curved, it has side pieces and is attached with a ball and socket joint. It would never hold a tray full of dishes (*cul de sac*). The thing (return to starting point) looks like some of the failures of an inventor. I wonder if the landlord is an inventor. No, you told me he was a porter in one of the big banks down town. The fellow is as big as a house and looks more like a prize-fighter than a mechanician; those paws of his would never do the work demanded of an inventor (blank wall again). This was as far as we got on the first day. On the second morning we got no nearer the solution. On the second night we talked over the way the porter and his wife lived, and the subject wondered how a man earning not more than $150 per month could live as our landlord did. I told him that the wife was a hairdresser and earned about eight dollars per day herself. Then I asked him if he did not see the sign "Hair-Dresser" on the door as we entered. The next morning after coming from his bath he said, "I saw that infernal thing again" (original starting point). "It must be something to use in washing or weighing the baby—but they have no baby (*cul de sac* again). The thing is curved at one end so that it would just fit a person's neck. Ah! I have it! The curve does fit the neck. The woman you say is a hairdresser and the pan goes against the neck and the hair is spread out over it." This was the correct solution. Upon reaching it there was a smile, a sigh and an immediate turn to something else (the equivalent of obtaining food after search). (From Watson, J. B., *Psychology from the Standpoint of a Behaviorist*. Philadelphia: J. B. Lippincott Co., 1924, p. 349-50).

We may agree with Watson that problem-solving is a trial-and-error process, if by that is meant simply that it often *proceeds in stages*, each of which contains the steps: (1) problem situation; (2) choice of concept; (3) verification; and (4) return to problem; until in the final stage verification leads to (5) solution. It would be wrong indeed, however, to conclude from this that there is any close resemblance between the behavior of a man solving a problem and that of a rat learning to run along a particular pathway in a maze.

Analysis of the Events in Problem-Solving. The chain of events in the solving of this problem is shown in Figure 9.3. The situation is set by the question "What is this thing?" and the visual stimulation provided by

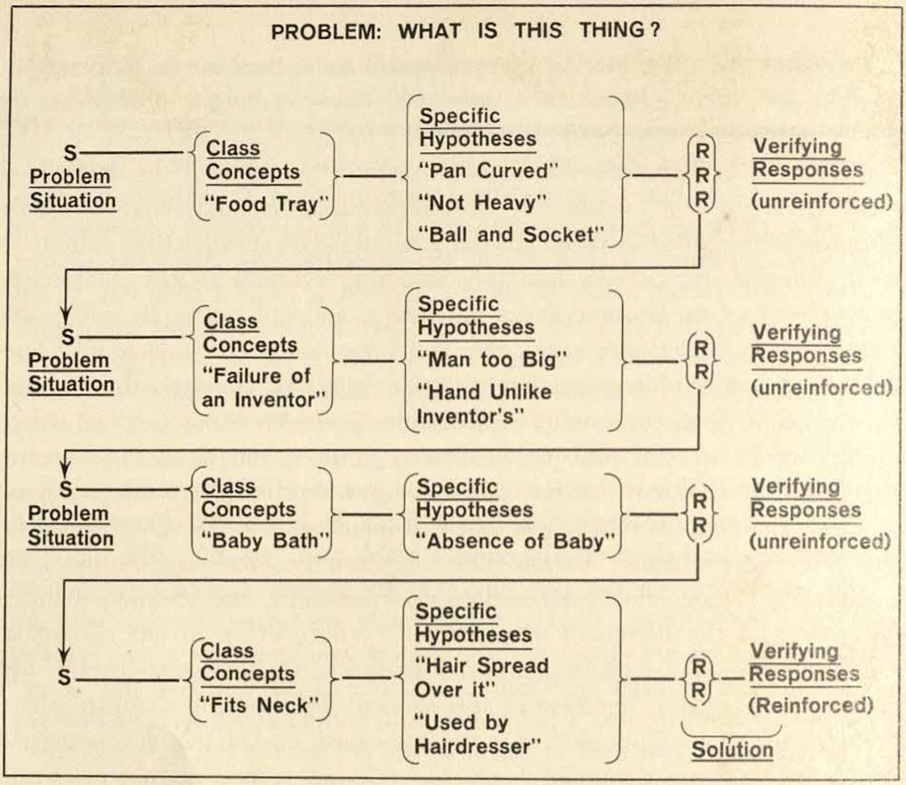


FIGURE 9.3. *Sequence of events in Watson's example of thinking. The solution of this problem, described in the text, required four stages. In the first three, the verifying responses were unreinforced, leading to the rejection of the concepts employed and a return to the problem situation. In the fourth stage, the conceptual sequence led to reinforcement of the verifying response, which is what is meant by "problem solution."*

the sight of the metal stand with attached tray. The individual responds to this stimulation with internal verbal responses which we recognize as being *class concepts*. He "thinks of" all possible classes to which this visual stimulus might belong; which is to say, these class concepts are aroused in his concept memory. Actually, it is probable that many more concepts are recalled in this way than he states aloud, as in Watson's example. We do know, however, that he recalls at least four different classes of objects, approximately described as "food tray," "failure of an inventor," "baby bath," and "fits the neck." From the store of class concepts that are recalled, one dominates all others in its ability to arouse the subsequent events in this chain. For reasons we know only incompletely at the present time, the *strongest* concept arouses one or more specific concepts referring to observable events in the environment. These are sometimes called *specific hypotheses*. In the example we are following, the concept "food tray" is strongest, and it leads to three specific hypotheses, as told by the individual in Watson's example. Stating them approximately, they are "a food tray is straight not curved"; "a food tray should be heavy enough to hold dishes of food"; and "a food tray should have a fixed joint."

Once these hypotheses have been stated, they control the actions of verification. In other words, the individual can now make overt *verifying responses,* which in this case take the form of a visual inspection. The tray is observed to be curved, and this response is therefore not reinforced. Similarly, the tray is observed as not heavy, and not having a fixed joint. These specific hypotheses are consequently weakened (or "rejected"). The process of non-reinforcement has its usual feedback effect on the original class concept "food tray," which is accordingly weakened also. In actuality, there may be a rather severe weakening of the strength of the concept "food tray" so that it no longer is effective in the problem-solving situation.

Since the concept which was first dominant has now been weakened in strength, the problem situation now takes on the character of line 2 of Figure 9.3. There is a new recall of class concepts, and another of these now becomes the dominant one, namely, "failure of an inventor." Again there is arousal of specific hypotheses, followed by verifying responses which are non-reinforced, a rejection of this concept, followed by a return to the problem situation. This process is repeated until one of the class concepts which has become dominant leads to verifying responses that *are* reinforced. In our example, these responses have to do with verification that hair may be spread on the tray, and with the statement of the wife's occupation as a hairdresser. The problem is solved. As Watson remarks, there is "a smile, a sigh and an immediate turn to something else . . . ."

Steps in Problem-Solving

Now that we have explored the main characteristics of problem-solving by using an example, let us see if we can give a formal description of it. Such a description obviously should be in terms of the steps in the sequence we have already outlined.

STEP 1. THE PROBLEM SITUATION. The stimulus-situation which begins problem-solving is composed of two parts—*the statement of the problem* and the *physical stimuli* which make the remainder of the situation. Both of these have important effects on problem-solving.

The statement of the problem may be provided by a question communicated by another individual, or it may be stated by the individual to himself. In either case, how the problem is stated may make a tremendous difference in the time and effort required in solution. Scientists, inventors, mathematicians, and artists have testified to many experiences of trying for weeks to solve problems which they were later able to solve rapidly when the questions which led to them were restated. Presumably, the restated question made possible the recall of concepts which were not aroused by the original question.

The best way of stating a problem for a given individual is indeed difficult to specify, since it depends on the peculiarities of his concept memory. However, it is evident that, if we want an individual to solve a problem, we must state it in terms which will lead to recall of concepts known to be available to that individual. We cannot expect a person lacking knowledge of differential calculus to solve a problem stated in terms of the concepts of that subject, for example.

Stimuli from the physical environment often have an essential role to play in solving a problem. A characteristic of mechanical puzzles, as well as magic tricks, is that the individual cannot observe all the stimuli necessary to the solution. The puzzle may have a hidden spring, or the magician may hold a palmed card. For this reason, puzzles constitute a rather special class of problems, and perhaps should not be considered typical of the category of problem-solving. As a further qualification on the importance of the physical environment, we recognize that some problems are of a sort which depends very little on physical stimuli. These are sometimes called "intellectual" problems. It is interesting to note that people sometimes seek to isolate themselves from physical stimulation while trying to solve problems of this character.

STEP 2. RECALL OF AVAILABLE CONCEPTS. The stimulus situation, provided by the statement of the problem and stimuli from the external environment, arouses the concepts which have been acquired by the individual through previous learning. The number and variety of such concepts which are available depend upon the *extent and variety of the individual's previous experience.* Anyone who tries to solve a problem must have a store of concepts available which is large enough to include the ones finally used in the solution. The probability of solution increases with the number of concepts available to the individual. This is true since the exact concepts necessary to solution cannot be foreseen, else there would be no problem.

Inventors, scientists, poets, and artists who have attempted to answer the question "How do you go about solving a problem?" have universally emphasized the importance of the step of learning all about the subject area in which their problem lies. They report that successful solutions appear to them to depend on a previous period of intense and sometimes extended "preparation." The function of such preparation must be the acquiring of as large as possible a store of concepts. The probability of problem-solution was high in those instances where the concepts acquired included those which finally turned out to be relevant to the problem. If an individual does not have a store of concepts that includes those that turn out to be necessary, the problem will not be solved. In such instances, the individual may need to undertake a new period of preparation, in which he adds to his store of available concepts.

How can we know what concepts are available to the individual? We can ask him to "think out loud," as Watson did. But this is obviously unsatisfactory, because the individual does not report *all* the concepts he has; instead, he tells us only those used in the verification process. We can, however, devise a test to measure the total number of concepts available to the individual in any given area. For example, suppose we asked the following question to a group of people: "A fire starts in a garage attached to a house in a suburban community. State *all* the things which could possibly have caused it." We should undoubtedly get lists which varied throughout the group from a very few class concepts to a great many. If we asked this question of an experienced fire chief, we should probably be able to elicit hundreds of concepts. It is not surprising that the fire chief's "experience" (by means of which he has obtained a large number of available concepts concerning causes of fires) enables him to solve many specific problems which would be impossible for the ordinary individual who lacks these concepts.

There would probably be another important difference between the novice and the expert in the concepts elicited by this question. This would be in the organization of the available class concepts. Whereas the inexperienced individual is inclined to have unorganized, and therefore incomplete, concepts about the causes of fire, an experienced fire chief would tend to categorize these causes in such a way that they thoroughly cover the situation. For example, the novice's list might run as follows:

match
spark from car distributor
short in electrical wiring
cigarette
oily rags

In contrast, the experienced person's conceptual structure might well look like that of Figure 9.4. This is not to suggest that he would necessarily recall these concepts in the order given in the figure; but merely to indicate their organized, *hierarchical,* nature.

The arrangement of concepts into hierarchies (in the "experienced" individual) is important because it makes possible the retention of a great number of specific class concepts. Some of these specific causes of fire in a garage may indeed be very improbable. But note that it is the fire that has the most improbable cause that takes an expert rather than a novice to

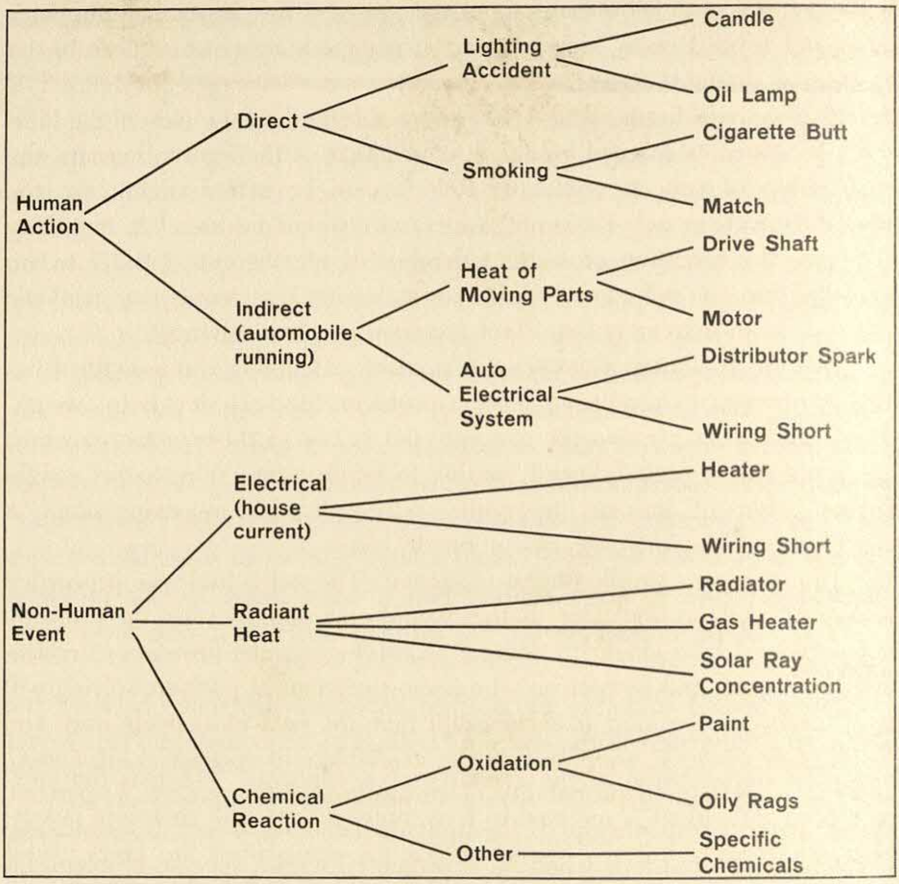


FIGURE 9.4. *A possible hierarchical arrangement of concepts applicable to the cause of a fire in a garage.*

solve. Both the expert and the novice might, on coming to the scene of a fire, spot an overturned kerosene lamp with equal ease. However, the relatively improbable cause of heat generated by chemical combination (not involving oxidation) would tend to be arrived at by the experienced person in a short time, whereas the novice might well fail to find this cause, because it was not available in his concept memory.

We do not imply that a novice cannot learn how to solve a specific problem involving an improbable cause of a garage fire; merely that it would take him much longer to do this. In the process of "learning how," he would undoubtedly acquire a number of new concepts to be stored in his memory, as well as a hierarchical arrangement of these concepts which might approximately resemble the one of Figure 9.4. Notice that in our example, the concepts originally available to the novice were simply: match, spark from car distributor, short in electric wiring, cigarette, and oily rags.

If he undertakes to learn more about the causes of fire, he may end up with these and a great many more, arranged in some hierarchical order. In the process of doing this, he may even *invent* some concepts for himself—a process we shall discuss later. It is impossible to say how closely the hierarchy of concepts learned would resemble that of the figure. Perhaps the relationship of concepts, item by item, would be rather slight. But the proof of effectiveness of a concept hierarchy would be found in its ability to insure the retention of a great number of specific concepts related to causes of fire. So we come back to the statement that *number of available concepts* is an extremely important factor in problem-solving.

STEP 3. WEIGHING CONCEPTS; JUDGMENT. Assuming the individual has all the necessary concepts to solve a problem, his next step is to "weigh" them. That is, he chooses the concept (out of two or three or more) which has the greatest probability of leading to verification. Why is this weighing, or judgment, process important? Why isn't problem-solving simply a matter of checking the concepts out one by one?

The answer is simply one of efficiency. The individual who proceeded to choose concepts one after another would undoubtedly solve the problem, but he would take longer in doing it. Carrying out the process of verification takes time, and the person who is most efficient at problem-solving will tend to choose the most likely concept first, the next most likely next, and so on. For example, suppose that the available concepts are A, B, and C, and that they have a probability of verification of 60 percent, 30 percent, and 10 percent respectively. If the individual chooses A first, B second, and C third on all occasions when he is presented with a specific problem, his problem-solving behavior over a period of time will be more efficient than that of a person who chooses any other order, or who chooses a random order. The situation is as shown here:

	Probability of Solution in 1 Verification	*Probability of Solution in 2 Verifications*	*Probability of Solution in 3 Verifications*
Order ABC	60%	90%	100%
Order BAC	30%	90%	100%
Order CAB	10%	70%	100%
Order CBA	10%	40%	100%

This means that, with the most efficient weighing of concepts A, B, and C, the probability of solution in only one verification is 60 percent, as compared to 30 percent and 10 percent if the concepts are otherwise chosen.

Supposing that the solution is *not* found in one verification, the probability of solution in a second verification is 90 percent with the most efficient choice of concepts (either AB or BA), as compared with 70 percent and 40 percent with the less efficient choices. For the specific problem, occurring once in ten times, which requires three steps in verification, obviously one order is as effective as another. The principle that applies to the whole situation, though, is that efficient weighing of concepts means choosing those with the highest probability of verification first.

How does the individual come to react to the most likely concepts first? Primarily, this depends on his past learning; that is, the *strength* of concepts at any given time is determined by the degree of reinforcement these have received (through the verification process) in the past. To return to our garage-fire problem for a moment, the experienced fire chief who weighs the concepts "Electrical wiring," "Radiant heat," and "Chemical reaction" as depicted in the bottom part of Figure 9.4 will undoubtedly choose them in the order given. To him their relative probability of verification (or relative strength), based on his extensive past learning, may be something like 55 percent, 40 percent, and 5 percent respectively.

Here again is a step in the problem-solving process that can strikingly reveal the effects of inexperience. Suppose we have a novice who has tried to find the cause of only a few fires. Suppose also that the most recent fire he saw was caused by a wiring short in the ignition while the automobile was running. Under these conditions, the concept of "Electrical (auto current)" may have a considerable degree of strength in this individual. In analyzing a second fire, he may tend to look immediately for a short in the auto wiring. Yet this is an inefficient procedure, on the whole. This concept, having considerable strength for this individual, may actually have a probability of verification which is quite low in relation to all other possible causes of the fire. Since verifying it takes time, the experienced individual, who chooses concepts in the order of their probabilities, has the greatest chance of solving the problem in the shortest possible time.

There is much evidence to show, too, that "prejudices" and "sets" can influence this weighing process to the detriment of efficient problem-solving. When an individual is given a series of mathematical problems, all of which are solved by the application of a single concept (rule), he may then have considerable difficulty in applying another, different concept to a new type of problem. His specific learning in the series of like problems has so increased the strength of a single concept that he is (temporarily, at least) unable to carry out the concept-weighing process efficiently. Prejudices can have a similar effect. A man who has had an accident involving a woman driver may be inclined to choose the concept "woman driver" first when seeking to explain the cause of another accident.

There is another qualification needed to make our description of judgment complete. In practical problem-solving situations, it is true that efficient performance may be determined by other factors than "probability of verification." If we are weighing concepts A (60 percent), B (30 percent), and C (10 percent), our choice may be additionally weighted by the different amounts of time and effort required to verify these concepts. For example, if A takes two hours to verify, B 15 minutes and C two minutes, efficient problem-solving may dictate that we use the order CBA, even though this is not efficient weighing so far as probability of verification is concerned. If, on the other hand, A takes 15 minutes, we should probably choose the order ABC in any case. In other words, it is possible that the strength of a concept is a function not only of its previous reinforcement but also of the anticipated effort required for verification. Thus we see that there may be a complex set of factors which influence this weighing process in human problem-solving.

The concept-weighing process can be seen to be the central and essential step in problem-solving. Unless we can show that this process actually occurs, we have no reason to believe that any given instance of behavior is not simply one of following a habitual course of action. Yet we cannot observe the judgment process directly, of course. All we can do is demonstrate that when the conditions for efficient concept-weighing are present, the solving of problems is in turn efficiently done; and when these conditions are not present, the solving of problems is inefficient.

STEP 4. AROUSAL OF SPECIFIC HYPOTHESES. Following the making of a judgment, in which one concept "wins out" over others, specific hypotheses are aroused concerning events that can be "checked" or observed. For example, if the chosen concept relating to the cause of a garage fire is "oil lamp," then a specific hypothesis may be "presence of an overturned or leaky oil lamp." Again, if the chosen concept is "short in house wiring," the specific hypotheses may be "presence of bare wires," "evidence of burned insulation," and perhaps others of a similar nature.

The major importance of this step in problem-solving is that it sets the stage for verification. Specific hypotheses must be available to the individual if his thinking is going to be successful and complete. Thus it would do little good for an individual to be able to choose the concepts "oil lamp" or "house wiring" unless these were connected to a conceptual bridge that told him to look for an overturned oil lamp or some burned insulation. Without these specific hypotheses, it might be said that the individual has an "intellectual" understanding of the problem, but no "practical" understanding.

Specific hypotheses are acquired in a manner similar to other concepts. They may be learned initially as verbal habits, but their retention is best insured when they are practiced in a sequence which terminates with a verifying response. This is the legitimate reason for the emphasis on "doing" and "practice" in education. The concept of electrical resistance is best learned by teaching the *consequences* of varying the diameter of a conducting wire, for example. And these consequences, in turn, are best established by asking the student to carry out the responses (using a battery, circuit, and meter) necessary to *verification* of these hypotheses. Or take an even simpler example. Why are young children asked to solve problems like this: George has five apples, and gives two to Jim; how many apples has George left? Why not, simply, five minus two equals what? The reason is that the first way of stating the problem represents an attempt to state concepts in terms that can be directly verified by the child. Stating it in the first way makes possible the learning of usable knowledge, whereas the second statement may be learned only as a verbal habit.

STEP 5. VERIFICATION. The final step in problem-solving is *verification*. As we have seen, the specific hypothesis is a verbal statement (usually implicit, rather than spoken aloud) which leads to the overt responses involved in verification. These are sometimes called "checking responses." In our example of the garage fire, they may be such responses as looking for the presence of an overturned oil lamp, observing bare wires in electrical circuits, smelling burned electrical insulation, and so on.

Sometimes verifying responses are simple, as in the case of those just mentioned; sometimes they are complex. A television repairman may in some instances make simple checking responses such as observing the presence of burned-out tubes. In other cases, he may make more complex checks involving the measurement of voltage in various parts of the circuit. A repairman for a radar set may have to make a series of checks of voltage, resistance, and wave form in order to test a single hypothesis. A physician may have to carry out an elaborate series of observations of physiological processes, including pulse rate, blood pressure, rate of basal metabolism, urine analysis, in order to put together a single verification of a hypothesis derived from his knowledge of disease. So, although verification is often a simple process, it is not necessarily so.

Obviously, the problem-solving process may go wrong in this final stage, just as it may in other stages. The individual may not make a careful or accurate check. A reading of 10 volts on a voltmeter may be read as 100 volts. The odor of burnt insulation may be detected where there is none. Three apples may be counted as two. Errors of observation like this have many causes. However, in problem-solving, we must be particularly aware of *motivational* causes. It is a strong human tendency to believe what one wants to believe, or even to see what one wants to see. Thus, a particular hypothesis may be appealing for many reasons, among them the reason that it leads to a final solution of the problem. Even if it is not the correct solution, it may be satisfying because it terminates the whole sequence of behavior. (Recall Watson's expression "a smile, a sigh and an immediate turn to something else . . . "). Because of this desire to regard the problem as solved, the verifying response is particularly vulnerable to common observational errors. It is noteworty that the scientist strives to avoid such errors by surrounding his observations with elaborate precautions. The solution of everyday problems, however, is seldom done under such ideal conditions. In general, the most successful practical thinkers are those who have learned to be exceedingly careful about verification responses.

The stage of verification is truly "final" only if it leads to a positive reinforcement which terminates the behavior sequence. If the verification cannot be made, that is, if the "check" is "negative," the process begins again, as we have seen. Another concept is "chosen" by the weighing process, other hypotheses of consequences follow, and new verification responses are made.

Can one "think out a problem" without verification? Of course, this can be done, and often is. There are many problems for which the verifications of specific hypotheses have been made so many times that the individual achieves a solution without making overt responses. As we have mentioned before, "intellectual" problems like those in mathematics may be brought to solution because they have been brought to a stage which has many times previously been verified (for example, reduction of an expression to a familiar integral form). On the other hand, the lack of verification in everyday thinking is what characterizes "wishful thinking," and "daydreaming." Although one may recognize the possibility of correct problem-solving without overt verification under special circumstances, the importance of this terminal step should not therefore be overlooked.

INVENTION

The process of thinking, as we have described it up to now, is one which can lead to correct solutions to problems if the necessary concepts are available, if they are efficiently subjected to judgment, and if their consequences are verified. In this process, we have assumed that the relevant concepts have either already been learned, or can be acquired by learning which, through reinforcement, establishes a connection between a verbal signal and an appropriate set of overt responses.

But the human being also encounters problem situations which cannot be solved in this straightforward manner. Sometimes, there are problems which are "new" or "insoluble," in the sense that the application of known concepts, good judgment, and adequate verification do not lead to a solution that terminates the individual's behavior. In such instances, the individual finds himself engaged in the process of *invention.* Invention is in fact the business of the scientist, the artist, the poet, and of many other creative individuals. It is this process which gives us new insights, new meanings, and new satisfactions by solving problems which have never been solved before.

What is it that is invented? It is probably not concepts in the sense that they are words-become-signals. Making up a new word is not ordinarily what is meant by the term "invention." But it is true that existing concepts may be given new meaning by invention. Consider the concepts involved in the elementary notion of the gas law $PV = kT$, and the subsequent invention of the kinetic theory of heat. The idea that the pressure exerted by a given volume of gas could be explained by conceiving that the energy of individual particles (molecules) of the gas could be increased by raising temperature was indeed a remarkable invention. What was new about it was not the concepts of pressure, or volume, or temperature, all of which existed previously. But the application of the concept of kinetic energy to this particular problem had not been made, and by making it, the concept of temperature was given an expanded and enriched meaning. Thus one important form of invention is the *extension of meaning of existing concepts by generalization to new situations.* The idea that "there is nothing new under the sun" gives a distorted kind of impression of this set of circumstances. The concepts were indeed not "new"; they were in existence. Nevertheless, their application to an additional problem led to the creation of a set of laws in which the same old concepts came to extend their generalizability to "new" physical situations.

Another kind of result of invention is the *creation of new concept hierarchies.* Recall that in our garage-fire problem we pointed out that an experienced man is likely to have his concepts arranged in a hierarchy such as that shown in Figure 9.4. Scientific invention also often takes the form of new hierarchies. The periodic table of the elements and the system of classification of living organisms (the Linnaean system) are two outstanding examples. Such classificatory schemes are not merely methods of description in science; they are ways of insuring the efficiency of scientific problem-solving. Thus they represent the invention of something new, even though the basic concepts which they organize may have been previously in existence.

The process of invention is difficult to study objectively, because it is so typically a "private" kind of affair. Often only the final overt response is observable, representing a correct solution, whereas the false tries which precede this solution may not be in evidence. In attempting to study invention, psychologists have set up miniature problem situations that are assumed to be "new" to the individual. These situations are chosen in such a way that the nature of the possible invention or inventions is known to the experimenter beforehand. Some examples of these studies are described in the next section.

SOME CONDITIONS AFFECTING PROBLEM-SOLVING

The application of concepts to problem-solution is a type of behavior which is affected by a variety of conditions, both external and internal. Two of the more significant conditions which have been studied experimentally are (1) the *availability* of relevant concepts and (2) the effect of *direction* or *set*.

Availability of Concepts

A number of experimental studies of problem-solving make a rather elementary point: if the required concepts are not available, the problem cannot be solved. For example, in a study of concept-learning in 4- to 6-year-old children the ability to solve a simple problem was shown to be dependent on the availability of concepts.[2] Beads of three different shapes were shown to these children (one child at a time), in a number of trials designed to have the child learn a concept for each. One type of bead was called VIM, another JID, and the third QUAP. Retention of these names was tested by asking each child to repeat the appropriate name for each bead when they were presented in random order. Finally, the child was shown a number of beads of the three types on a table, and was given the instructions "Put all of the QUAP on one side of the table and all of the JID on the other side." Of those children under four years of age, only 21 percent solved this problem after learning the names of the beads. It was solved correctly by 67 percent of the five-year-olds and by 100 percent of the six-year-olds. Thus, although all the children were able to learn a name as a verbal habit, the availability of these names as concepts useful in solving this simple problem was clearly related to age.

The dependence of problem-solving on the availability of concepts in adults was demonstrated by using a series of matchstick problems similar to those shown in Figure 9.5.[3] Using elementary problems as examples, the experimenter undertook to train one group of individuals to use an "arithmetical" principle (rule), which may be paraphrased somewhat as follows: "A stick can function as a side of two adjacent squares. Therefore, to re-

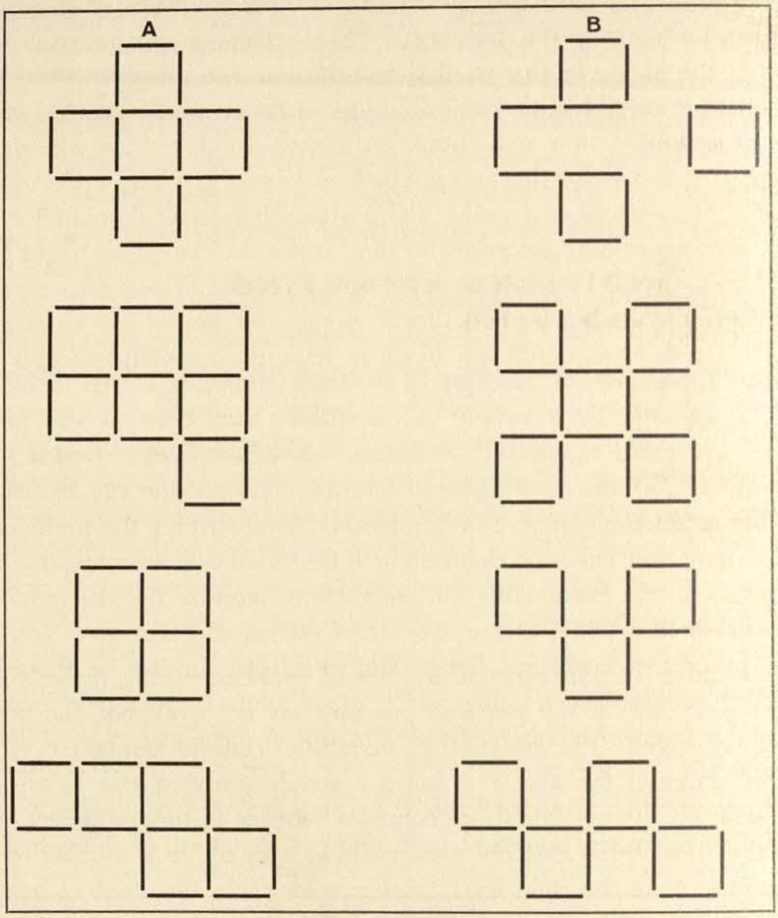


FIGURE 9.5. *Match-stick problems. Each A figure is to be changed into the corresponding B figure by moving only three matches (two in the case of the bottom pair). Each problem may be solved by using an "arithmetical" rule or by a "configurational" rule. (After Katona, from Woodworth, R. S., and Schlosberg, H.,* Experimental psychology *(Rev. Ed.). New York: Holt, 1954)*

duce the number of squares which can be made with a given number of sticks, make the squares non-adjacent; to increase the number of squares, make them adjacent." A "configurational" principle was taught to another group of individuals, again using simple problems as examples. This rule may be stated like this: "A pattern of sticks may be either compact or loose. Loose patterns have open spaces, either corner holes or side holes. Opening up holes in a pattern with a given number of sticks decreases the number of squares; closing holes increases the number of squares."

These rules were not taught as verbal statements in this experiment; rather it was expected that they would be derived from examples designed to lead the individuals to see the figures in these two ways. A third group of individuals was given training in which they simply memorized the moves required in one or two of the problems. The question asked in the experiment was, which kind of initial training leads to the greatest transfer in the solution of new matchstick problems? In this study, the greatest transfer was found for the group which had been given an opportunity to learn the "configurational" rule, and a somewhat lesser amount for those who had been taught according to the "arithmetic" rule. As might be expected, both were better in solving new problems of a similar sort than were the individuals who had simply memorized steps. The latter group, in other words, was much less likely to have the relevant concepts available.

Set or Direction

The instructions given to an individual in describing the problem may have a significant effect on the time he takes to solve it, or even on whether he ever solves it. Presumably, the instructions increase the strength of certain concept-hierarchies at the expense of others, and thus give "direction" to the process of problem-solving. Similar effects can also be obtained by providing preliminary training which gives reinforcement to a particular concept or concept-hierarchy by designating a particular type of solution as "correct."

Anagrams like those of Table 9.2 were employed in one study of *sets* established by instructions and by training. One group of individuals was

TABLE 9.2

EXAMPLES OF ANAGRAMS USED IN STUDIES OF THE EFFECT OF SET IN PROBLEM-SOLVING

SINGLE SOLUTION ANAGRAMS		MULTIPLE SOLUTION ANAGRAMS				
Anagrams	*Solution*	*Anagrams*	*Solutions*			
idnkr	drink	mlsup	plums	lumps	slump	
oabnc	bacon	tdesa	dates	sated	stead	
nooni	onion	iovle	olive	voile		
etebs	beets	drabe	bread	beard	bared	debar
snabe	beans	eskat	steak	takes	stake	skate
vesno	ovens	ridfe	fried	fired		
clnuh	lunch	aseft	feast	feats	fates	
fiken	knife	malcs	clams	calms		
kosfr	forks	rasyt	trays	satyr	stray	
ladsa	salad	altpe	plate	petal	leapt	pleat

(From Rees, H. J. and Israel, H. E., An investigation of the establishment and operation of mental sets, *Psychol. Monog.*, 1935, No. 6.)

told to look for "eating words" in a series of twenty anagrams which included ten of the sort shown in the third column of this table. These anagrams, it will be seen, have several possible solutions, one of which pertains to "eating." A second group of subjects was simply told to solve the same twenty anagrams, no suggestion being made about "eating words." The number of "eating solutions" averaged 60 percent in the first group, but only 36 percent in the second, "undirected" group. In a second study, preliminary training rather than instructions was used to establish a set. In this case, one group of individuals was first given a set of anagrams like those in the first column of the table, which had only one solution, and that an "eating" solution. A second group was given training on a comparable set of anagrams having a single solution not relevant to eating. Then the two groups were asked to solve a standard set of twenty anagrams having multiple solutions, ten of which (like those in column 3) had one "eating" solution. Again the results showed a considerably higher percentage of "eating" solutions by the group having a *set* in this direction, this time established by the preliminary training.

Sets acquired by previous practice may also interfere with correct solution. If the new problem is similar in its external appearance to ones previously practiced, a concept-hierarchy or a rule learned in the first situation may be carried over to the second, as we have just seen. But the new problem may actually require a different rule or concept-hierarchy for its efficient solution. Effects of this sort have been studied extensively with the use of "water jar problems."[4]

In a typical study, individuals were told to suppose they had three jars, each holding different numbers of quarts of liquid. By filling and emptying two or more of the jars in certain sequences, they were to arrive at a required measured amount of liquid. Here is the sequence of problems which were presented:

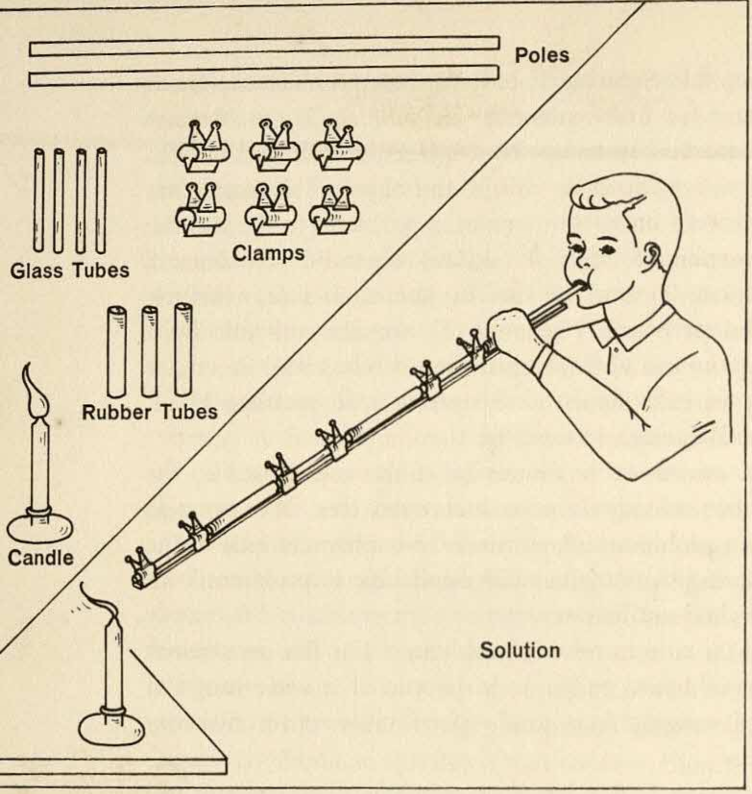
No.	*Jar provided (quarts)*			*To measure*
	A	B	C	
1	29	3		20 qts.
2	21	127	3	100 qts.
3	14	163	25	99 qts.
4	18	43	10	5 qts.
5	9	42	6	21 qts.
6	20	59	4	31 qts.
7	23	49	3	20 qts.
8	15	39	3	18 qts.
9	28	76	3	25 qts.
10	18	48	4	22 qts.
11	14	36	8	6 qts.

All the individuals in this experiment had the first problem explained to them after working on it for a few minutes. The rule is, fill the 29-quart jar and pour from it 3 quarts (by using the 3-quart jar) three times. In other words, $29 - 3 - 3 - 3 = 20$, or $A - 3B =$ the required amount. One group of individuals then went on to the remaining problems in the list, the second problem being explained after 3 minutes of work. Problems 2 through 11 (except number 9) are solvable by the same rule, which is $B - A - 2C$. However, problems 7 through 11 are also solvable by a simpler rule, which makes no use of the largest jar; namely, either $A + C$ or $A - C$. A second group of individuals, after starting with problem No. 1, were given only problems 7 through 11 to solve.

The operation of set was shown in the results of this experiment by the fact that the majority of individuals who had used the three-jar rule ($B - A - 2C$) in solving problems 2-6, continued to apply this rule in the remaining problems, ignoring the simpler rules applicable to problems 7-11. The control group, which had not had experience with problems 2-6, readily adopted the simpler two-jar rule in solving problems 7-11. The persistence of set in this problem was found to apply to people of a wide range of academic ability and age, ranging from grade-school children to university graduate students.

Presumably, the operation of sets based on previous reinforcement history is what accounts for the experience of "getting stuck in a blind alley" in solving either everyday practical problems or intellectual problems. Some studies have shown the importance of laying aside the problem when such circumstances arise, for a period of "incubation." In such a period, the dominance of an irrelevant set may be reduced and other concepts may get a chance to reassert themselves. Thus when one returns to the problem situation, it may be possible to take a fresh approach, using a new set of concepts.

The importance of continually searching for new "directions" rather than persisting in unsuccessful ones is emphasized by experiments using problems like that illustrated in Figure 9.6. In this study, one group of students worked at the problem of blowing out a lighted candle from a distance of eight feet, having available the materials shown, but with no other instructions. They were required to write out a description of a solution to the problem; they did not actually handle the materials. A second group of students was given a preliminary lecture of 20 minutes' duration, before being confronted with the same problem. This lecture emphasized the importance of seeking new directions, "avoiding staying in a rut," "keeping the mind open for new meanings," searching continually for "new combinations." The lecture was found to be effective in helping the students overcome the effects of incorrect sets. Sixty-eight percent of the group which



GURE 9.6. *The candle problem, requiring the individual to put out a ghted candle from a distance of 8 feet, using the materials shown. (After Iaier, N. R. F., An aspect of human reasoning,* Brit. J. Psychol., *1933, 24, 4-155)*

heard the lecture wrote satisfactory solutions to the problem in the time allowed, whereas only 48 percent of the control group did so. The results suggest that the individual problem-solver may give himself instructions which weaken the effects of undesirable sets, and thus encourage the appearance and use of a greater variety of concept-hierarchies in a given problem situation.

SUMMARY

Concepts function as internal stimuli to control the arousal of previously learned habits and skills. They thus enable the individual to *control* his own and other people's behavior. In addition, they make possible the *generalizing* of previous experience to a great variety of new situations. Finally, they are used in the processes of *thinking* and *problem-solving.*

An external stimulus which arouses the same concepts in two or more individuals is called a *symbol.* Symbols function in communication. By a process of learning, words are first reacted to as symbols by the young child, and are later used by him to arouse concepts in himself and others. The meaning of concepts is conveyed by words, and also by the context of words in sentences.

The generalizing function of concepts makes it possible for human behavior to transcend the limitations of specific habits, and also the restricted generalizing which is possible because of *stimulus generalization.*

Broadly defined, *thinking* includes the entire set of behavioral functions which utilize *concepts.* Generalizing with concepts to new situations characterizes even the most elementary forms of thinking called *imagining.* When *verification* of the responses generated by thinking is possible, we speak of *reasoning. Problem-solving* is the most complex form of reasoning. It occurs typically in a number of steps, each one characterized by a "weighing" of alternative concepts, called *judgment.* As a result of these events, the final course of action is chosen.

The steps in problem-solving are as follows. Step 1 is the occurrence of the *problem situation,* which includes both the verbal *statement of the problem* and the *physical stimuli* confronting the thinker. Step 2 occurs when these situational stimuli arouse the *recall of available concepts.* Basically, the more relevant concepts the individual has, the higher the probability of his solving the problem. The experienced problem-solver probably has his concepts arranged in *hierarchical order,* facilitating retention of them. Following the recall of concepts, there is the process of weighing them, or making a *judgment* to determine the course of action. The evidence indicates that individuals make judgments based upon the probabilities of success which have previously been experienced. It is possible also that such factors as *effort* and *time* required for alternative courses of action may be accurately reflected in the judgment process. Step 4 is one of arousal of *specific hypotheses* referring to observable events; these concepts are stored like others, and recalled in a similar way. They are the concepts which arouse the overt responses required in *verification,* the final step in the process (other than a possible return to the problem situation, if verification fails). The process of verification, essential as it is to efficient problem-solving, is often subject to observational and other errors in which the individual "sees what he wants to see."

Sometimes a problem cannot be solved by dependence on a process which uses previously learned concepts. Something new may be required, and the process of *invention* may come into play. So far as can now be estimated, the functions which invention serves are to *extend the meaning* of existing concepts, or to *create new hierarchies* of old concepts.

READING REFERENCES

Johnson, D. M., *The psychology of thought and judgment.* New York: Harper, 1955. A textbook on thinking, concept formation, and related processes.

Osgood, C. E., *Method and theory in experimental psychology.* New York: Oxford, 1953. A textbook of experimental psychology, with chapters on thinking and problem-solving.

Patrick, C., *What is creative thinking?* New York: Philosophical Library, 1955. A book on problem-solving and the various views philosophers and others have had about it.

Piaget, J., *The construction of reality in the child.* New York: Basic Books, 1954. An account of the development of concepts of objects, time, and space in children, by an outstanding Swiss psychologist.

Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954. A basic textbook describing experimental studies; includes a chapter on problem-solving.

10

SOCIAL BEHAVIOR

The habits, skills, and conceptual behavior of any human being are acquired and used within a social environment. In analyzing the social influences upon a person, we can focus on any one or more of four levels: the broad cultural environment, or the social class he belongs to, or the smaller groups he belongs to, or his relations to one other person. Analyses of this type use the concepts of status and role. Our discussion also explores the meaning and significance of attitudes, group norms, communication, leadership, morale, and other organizational factors.

We have now taken a detailed look at the varieties of activity which make up individual human performance. We have seen how these activities are energized and guided into specific channels by motivation, and how increased levels and types of skills are acquired through the interaction of the individual with his environment. The influence of the environment is of tremendous importance in the determination of behavior, and of particular significance is the *social* environment. In this chapter we want to take a closer view of this social environment; in other words, we want to examine how the individual reacts to, and interacts with, other people.

The newborn infant is immediately dependent on other people. Throughout childhood and adolescence, he finds his behavior is rewarded or not rewarded by other people, be they parents, childhood associates, school teachers, or ministers. As an adult, he assumes obligations toward his own family, toward his community, his church, his lodge, or his profession. Social influences of one kind or another are so pervasive they determine the style of clothing he will wear, the charities he may contribute to, and the type of moral life he leads. In addition, we know that the individual himself is continually attempting to influence other people, in all kinds of ways. In Chapter 4, we discussed a number of ways in which the social environment affects the individual, and in turn may be affected by him, through the *social motives.*

Now we shall take up two interconnected themes. Mainly, we shall be interested in examining the forms which social behavior takes, when we consider individuals as parts of larger social groups. What kinds of entities do we refer to when we speak of society, "culture," social class? What are the characteristics of social groups, and how do they form and maintain themselves? What is the nature of "morale" and leadership"? How do concepts affecting our behavior toward other people, called attitudes, develop in the individual and how are they measured?

A second theme is the influence of social factors on individual performance, as well as on the performance of groups in which individuals are working together. Nowadays there is much emphasis on teamwork. People are organized into crews and work groups, staffs and committees. What principles are there about how to organize groups which will be effective? How does the behavior of the leader affect the behavior of other group members? Further, what effect does the structure of organizations, such as those occurring in industry, have on the performance of the individuals who comprise them?

CULTURAL INFLUENCES

There are really four levels at which we can examine social influences in behavior. We may focus on the larger cultural environment, or the social class, or the immediate group to which a person belongs. Or, finally, we may study the most basic kind of interpersonal relationship, namely, that which exists between two individuals. We shall turn first to a description of some cultural influences on behavior.

Culture has been defined as the "sum total of behavior patterns, attitudes and values, shared and transmitted by members of a given society."[1] Reduced to simple terms, culture represents a common way of behaving of a large group of people. Each culture has a *distinctive pattern* of its own which is reflected in the behavior of all its members. This fact is especially important because it makes possible certain predictions about human behavior. Knowing the culture of which the person is a part helps us predict certain aspects of his behavior, just as knowing about his abilities and skills helps us to predict other aspects.

There is nothing mysterious about how culture influences behavior. The same principles of learning which we have previously discussed are much in evidence. A person born in a certain geographical area tends to develop particular goals and common ways of achieving these goals. The adults in this area tend to perpetuate their own behavioral characteristics by the selective use of reinforcement in controlling the learning of their children. Ways of behaving which are not socially acceptable are not reinforced and consequently undergo extinction over a period of time.

The range of cultural differences is much greater than one might assume. For example, the Zuni Indians, in our own Southwest, are a mild, inoffensive people. To them, *ceremonial* activity is a central feature of their lives; they spend the greater part of their waking time in some aspect of ceremony. By so doing, they are, in essence, able to avoid some of the disrupting influences of individualism and initiative. In contrast, the Kwakiutl Indians of the North Pacific Coast are extremely competitive and individualistic. For them a dominant behavior pattern is to increase one's own *social status* and reduce that of one's rivals. A man may compete for a blanket, not because he needs one, but because there is value in owning more blankets than his rival. Almost every phase of community life—religion, marriage, business—is conducted in these terms. The Pueblo Indians have a pattern which provides still a different contrast. In the Pueblo culture, acts of competition are regarded as being in bad taste.[2]

Cultural patterns change over periods of time, but ordinarily very slowly. However, cultural patterns may change more rapidly because of some additional environmental condition. Technological change, for example, has speeded up cultural change in many remote societies, as well as in our own. Interactions with other cultures can also facilitate change, as is shown by recent changes in dress and work habits in Far Eastern and Arab countries, resulting from increased contact with Americans and Europeans. Some aspects of culture may change while other aspects resist change despite considerable contact with other cultures. The Amish, Hutterite, and Mennonite sects within our own country are examples of such resistance to change.

Legal factors can influence cultural change. An example is the change in the behavior and the values of religious groups regarding polygamy. Changes in the cultural patterns of the South are being altered in some degree by recent legislation pertaining to integration of Negroes in public schools. Cultural changes in certain values took place in Germany as a result of the application of international law. It should be stressed that laws themselves do not change the culture. It is rather the patterns of reinforcement resulting from laws and law enforcement which bring about the changes.

INFLUENCES OF SOCIAL STRUCTURE

As we indicated earlier, knowing where a person comes from helps us understand and predict his behavior. If we know that a boy is from a Pueblo tribe rather than a Kwakiutl tribe our chances of predicting his behavior in a competitive situation are improved. However, most of the time we are not faced with such gross predictions. We usually live within a given culture, and we try to understand the behavior of individuals around us in that culture. Upon close examination it turns out that each culture has a *social structure* all its own, and consists of subcultures called social classes. In some societies, like our own, this structure is not particularly rigid, but it still exists and exerts influences on the individuals within it. What are some of the characteristics of social structure?

The Concept of Role

People differ in the kinds of relationships they have with one another in a particular society. Hence, people become differentiated and categorized in terms of the *roles* they play in the social group. By "role" we mean the part an individual plays as a result of occupying a particular position or status in a society. For example, by virtue of the fact that an individual born into a family is a male, he plays the role of a son. Similarly, as the result of occupying other positions in a social group, other persons play such roles as father, mother, friend, and worker. In less complex societies, roles are often assigned in accordance with individual capabilities. The role of warrior is ascribed to the young, the role of wise man to the old, and roles of less importance in the social structure to children.

Any individual has several roles, and he has different patterns of behavior to go with each role. Thus, a man may be at one and the same time a worker, a son, a father, a church member, and so on. What makes the *role* of such importance is the fact that it largely determines how people will act towards other people. Individuals are expected to exhibit particular patterns of behavior in particular roles. The role of father requires certain duties, allows certain privileges, and determines certain relationships with others. Similarly, the roles of factory worker or manager each imply certain duties, rewards and relationships, as well as particular attitudes and beliefs.

In general, people learn to shift roles easily. Thus, in the role of father the man assumes a dominant role at home, but as worker at the plant he assumes a subordinate role in the department. The college professor acts one way in class, but at a party, even with his students present, he is expected to act differently. If he sticks to his academic behavior at the party, or to his party behavior in the classroom, he is not acting in accordance with the social structure. "The Admirable Crichton" by Barrie is perhaps one of the best-known examples in literature of the alteration of roles by circumstances.

Sometimes, conflicts occur between roles. A lawyer who learns in confidence that his client really did commit the murder is caught between his citizen role and his professional role. The foreman who catches his friend in a rule infraction similarly finds himself in a role-conflict situation. Changes in status may result in role conflicts. The movie star who is drafted as a private in the Army may find the role learned in one status no longer appropriate for his new status. But despite the existence of such conflicts, we are typically able to change readily from one role to another.

Authority Structure

A second important feature of social structure is the amount of power and authority assigned to the various roles which occur in it. Each society assigns more authority to certain roles than to others. In the family, authority is usually assigned to the father's role; in the plant, to management's role.

The authority structure tends to organize the different roles in a society. It is the way a given social system coordinates and controls the interactions among the members of that society. Without authority of some kind, we should not have a social structure, but only a variety of different roles. Of course, the form and source of this authority structure varies tremendously from one social system to another. We shall have more to say about this aspect of social structure, when we examine social relationships within industrial organizations.

Status

As we have seen, *status* refers to the position a person occupies within a system of social relationships, whereas role refers to his behavior in that status. Another important characteristic of social structure is the status hierarchy which develops within this structure. Different statuses are seen by members of society as differing in importance and desirability. The people within a society tend to rank statuses along a scale of prestige, and they show different amounts of honor and deference to people in these roles.

Persons in positions of high authority may rank high in prestige, as in an army or in industry, but this is not necessarily the case. Medical doctors rank near the top of prestige scales in our society, yet their authority is low. On the other hand, a politician may have high authority but low prestige.

In an industrial work group, the man with greater seniority is sometimes assigned higher prestige-status than the foreman.

The factors which contribute to these status differences vary with the nature and goals of the society. In our society the banker and industrialist enjoy high status. Theoretically, at least, communist countries accord higher status to the worker and farmer. In militaristic countries, the soldier is in a high status position. In our own society, we may note the difference in prestige of the soldier during wartime with his prestige in the same community during peacetime. In the more primitive cultures, high status tends to be assigned in accordance with the needs of the society. In complex cultures like ours, in which societal goals are less well defined and certainly more diversified, many factors contribute to prestige. We are inclined to assign higher status to the movie star than to the physicist. It is not unlikely, however, that the status of the physicist will increase as his contribution to the needs of society becomes more widely known.

OCCUPATIONAL STATUS. In a highly industrialized society, status differences are often tied to occupations. In England, for example, considerable prestige is derived from land ownership. In the United States, bankers and financiers rank high in status. The civil service worker in this country enjoys less respect than in England. In our society, intellectual and artistic pursuits are not, in general, accorded as high status as they are in Far Eastern and European countries. Many of these differences are rooted in the history of a particular society. The distinction between white and blue collar workers may be a good example: white collar work has a higher prestige even though certain blue collar workers are often paid more, and may require more skill. In part, the reason for this difference in status may be traced back to feudal times, when manual work was looked upon as degrading.

STATUS SYMBOLS. Any discussion of status must consider the existence of *status symbols.* We frequently do not judge the status of other individuals on the basis of careful study. Instead, we identify the status of other people by symbols which simply go with status, although they do not necessarily confer the status. For example, the rug on the executive's floor or the doctor's stethoscope do not in themselves confer status. Yet the young supervisor may seek a rug, and the new intern may go out of his way to hang a stethoscope around his neck before entering the corridor. During World War II, new pilots would sometimes work over a new uniform cap to give it a "20-mission crush." What was sought was the status symbol itself, rather than the achievement which actually conferred status. The railroad worker of a certain rank carries his oil can, even though he has no immediate oiling to do. The boss wears his coat in the hot stuffy factory rather than leaving it in his office, in order not to be without his status symbol.

People with actually low status often go to great lengths to seek symbols of high status. Elaborate fraternal orders are frequent among lower-middle and lower social classes, as well as among minority groups with low status. A man may sweep floors by day and yet be the Grand Imperial Dragon Wizard, complete with full regalia, at night.

Industry is full of status symbols. The most obvious are job titles, in which minor changes in wording are often important. Another mark of status is the method of pay. A person may prefer a fixed salary to an hourly rate purely on the basis of status implications. Clothing and insignia are other marks of status (for example, the white versus the blue collar). The Brooks Brothers suit may distinguish the executive from other male office workers. Work-place is still another symbol of status. Typists work in a large room, secretaries in a private office. Closeness of one's desk to the boss's office is often a mark of status. And then there is, of course, the key to the men's washroom. (In a recent Broadway play about the advertising business, this was actually a "gold" key.) Once such status symbols are conferred they may be difficult to remove. Changing a man's desk or office, or removing his phone, may be seen as a loss of status, when none was actually intended. The result may still be a change in the worker's behavior and in the behavior of others toward him.

System of Rewards

Besides the characteristics of role, authority, and status, there is a fourth characteristic to social structure which should be mentioned. Each society establishes a way of distributing among the roles the rewards produced by the social system. In some cases the rewards may be concrete ones, for example, money or goods. In other societies rewards may include less tangible benefits. Often, for example, rewards are distributed according to prestige. Or, they may be distributed according to skill, type of occupation, seniority, or in accordance with a tradition. The important point is that the distribution of rewards is never a random matter. Instead it proceeds according to a definite scheme which gives to certain roles more rewards than others. We shall see something of the complexity of such a reward system, consisting of monetary and other rewards, in our further treatment of industrial society.

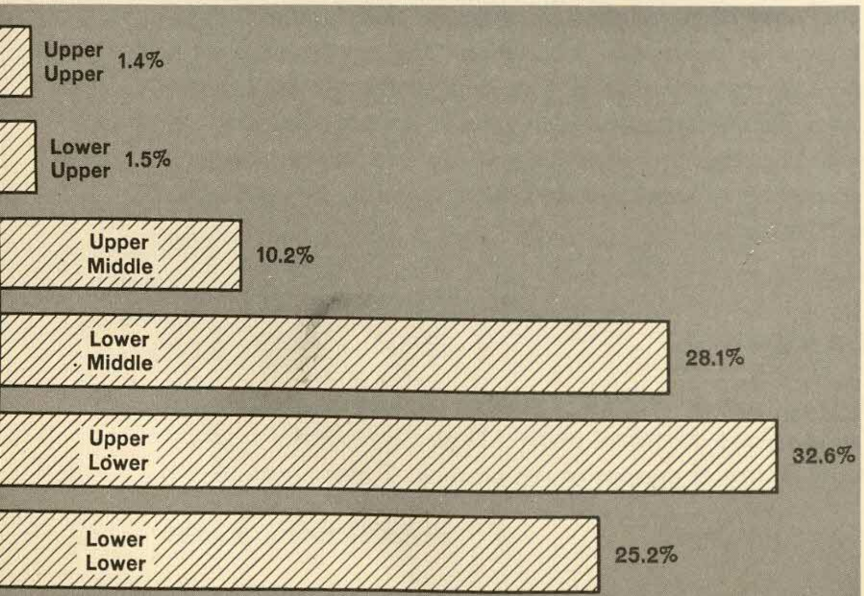
SOCIAL CLASS

Society consists not merely of a large number of different statuses and roles, organized in the ways described above. Typically, societies organize statuses into broader groups of persons of similar rank. Persons with wealth come to know one another, join associations for common benefit, create exclusive clubs, and encourage their children to intermarry. When persons of similar status begin to act together and develop attitudes of mutual interest which are different from those of other groups, *social stratification* is said to take place. The terms "social strata" and "social class" imply a differential ranking of large segments within a social system into levels which feel superior or inferior to other levels. In some cultures such classes are rigidly defined. For example, in the feudal system all members fitted into one of three classes—nobility, freemen and slaves. A person had virtually no chance to change his class, and the class a man belonged to restricted the occupation he might take up. Marked contrasts in speech, dress, and social behavior existed between the individuals of the different classes. The caste system in India exemplifies this system in today's world.

In our society social strata still exist, but they tend to be less formalized and more flexible. It is very difficult to specify the criteria that clearly distinguish one class from another. As an example, a study was made in a town given the fictitious name of "Yankee City," in which a large number of citizens were asked to rate their fellow townspeople on social status. These people generally had little difficulty in classifying everyone in town into three major classes, each with an upper and lower part. Figure 10.1 indicates the percentage of people placed in each class.

When asked on what basis they rated their fellow citizens, the people of this town mentioned a variety of criteria, including such factors as *nature*

IGURE 10.1. *Social class in "Yankee City." The figure shows how the citizens of a ew England town were "stratified," as determined from interviews and other ecoomic and social information. (.8 percent were classified as unknown). (Data from arner, W. L., and Lunt, P. S.,* The social life of a modern community. *New Haven: ale Univ. Press, 1941)*



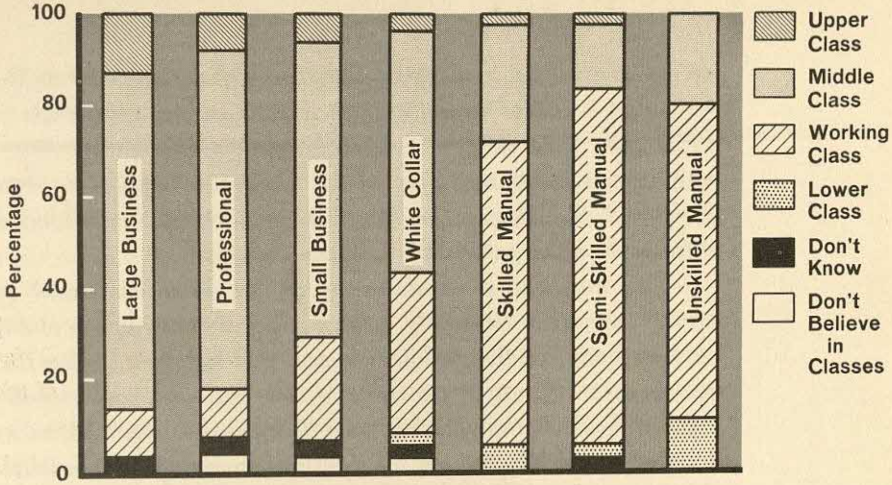


FIGURE 10.2. *The relation between social class and occupation. Members of each of the occupational groups (represented by the seven bars) were asked to identify themselves with a social class. The shadings in the bars show the percentage of each occupational group choosing each class. (After Centers, R. T.,* The psychology of social classes. *Princeton: Princeton Univ. Press, 1949)*

of occupation, kind of income (salary, commission, etc.), *family genealogy, moral standing, social relationships* and *organization,* and *residential area.* There are undoubtedly many others.

When people are asked to classify themselves according to social class, they tend to judge themselves mainly by their occupations. Figure 10.2 shows that the higher a person is on the occupational scale, the higher is the social class in which he places himself.

The important thing about social strata, for our present purposes, is that people identify themselves and others with certain social classes, and this identification influences their behavior and attitudes. There appear to be common attitudes and behavior patterns which are characteristic of certain classes. In examinations of voting behavior and opinion-poll surveys, high correlations are obtained between people's responses and their social class. For example, upper classes tend to be more conservative, lower classes less conservative. Another instance of the strong relation between social class and behavior comes from studies of child-rearing practices in the middle and lower classes. In general, middle class parents are found to be more rigorous with respect to cleanliness and eating, and also tend to give their children more responsibility at lower ages.

The mechanism by which class influences behavior is, of course, similar to those outlined for culture in general. The kind of neighborhood in which the individual lives, the kinds of playmates he has, the kind of home environment in which he grows up, all serve to determine patterns of reinforcement for learning. They have a profound effect in determining behavior as well as in perpetuating the social class. Even the individual's goals and levels of aspiration are related to his social class. One effect of social class is to restrict a person's occupational perspective to those jobs with which other members of his class are familiar or sympathetic. In Chapter 5 on "Human Abilities" we also noted the influence of early environment on the pattern of abilities developed.

The importance of status needs has been discussed previously. In American culture especially, individuals are motivated to change class membership from one that is lower to one that is higher in the status hierarchy. Sociologists refer to these shifts by the term *vertical mobility*. There are many difficulties in achieving such changes, but the barriers are continually decreasing. While we are all aware of many specific examples of remarkable vertical mobility, research findings show that an individual's most likely occupational level is the occupational level of his father. An example of this is shown in Table 10.1. In other words, there is still a great deal more "horizontal mobility" within such categories as professional, semiprofessional, skilled trades, and unskilled jobs than there is upward mobility between these categories. The son of a professor or banker still has the option of following in his father's footsteps. The option of becoming a professional man, while available to the son of a factory worker, is a much longer vertical step for him.

TABLE 10.1
RELATIONSHIP OF SONS' OCCUPATIONS TO FATHERS' OCCUPATIONS

Fathers' Occupation	Sons' Occupation		
	Nonmanual	*Manual*	Total
Nonmanual	1,573	918	2,491
Manual	1,651	4,150	5,801
Total	3,224	5,068	8,292

(After Jenson, P. G. and Kirchner, W. K. A national answer to the question, "Do sons follow their fathers' occupations?." *Journal of Applied Psychology*, 1955, 39, 419-421.) As the table shows, 71 percent of sons of fathers in manual occupations also enter manual jobs. Similarly, 63 percent of sons of fathers in nonmanual occupations also enter nonmanual occupations.

GROUP BEHAVIOR

Thus far we have considered the effects on behavior exerted by the largest sociological unit, culture, and by a smaller unit, social class. We shall now examine the influences of a still smaller social unit—the group. While many of the characteristics of larger social units are found in smaller groups (e.g., roles, status hierarchies and symbols), there are a number of unique characteristics of smaller groups. Since groups such as teams, crews, and work groups are numerically smaller, it is often possible to study the behavior of everyone in the unit. For this same reason, it has been possible to study group behavior experimentally in laboratory situations.

Everyone is a member of a large number of different groups. These may include a family group, a church group, and an industrial group, to name a few. When the individual functions as a member of a particular group, his membership in this group affects his behavior. In this section we shall first describe a pioneer experiment which showed the importance of belonging to a group on the performance of its individual members. We shall then consider in greater detail the characteristics of groups, and the specific ways in which these characteristics influence behavior.

The Hawthorne Studies

A series of pioneering studies were carried out at the Hawthorne Works of the Western Electric Company.[3] These studies were begun in 1927 and continued for a period of 12 years. They began as an investigation into the effects of illumination on worker productivity. In later phases the influence of other factors, such as hours of the work-day, rest pauses, hours of the working week, and pay incentives were studied. We cannot consider here the many findings of these studies. The result most relevant to our present discussion is that social factors were found to be more important in affecting worker productivity than the environmental changes themselves. Especially important for production improvement were factors in the group to which different employees belonged.

In studies of illumination the production of inspectors, coil winders, and relay assemblers was measured under four different lighting conditions. For the inspectors it was found that production rose and fell without any relation to the illumination. Among the coil winders and relay assemblers productivity increased, but not in any direct relation to the increase in illumination. However, after such increases occurred and illumination was then decreased, production did not decrease. Additional studies showed that productivity increased even in groups in which the light bulbs were merely replaced with other light bulbs of the same intensity. The experimenters had stumbled onto the importance of employee attitudes and motivations.

In order to exercise greater control over their experiments, the investigators decided to study intensively a small group of employees in a separate

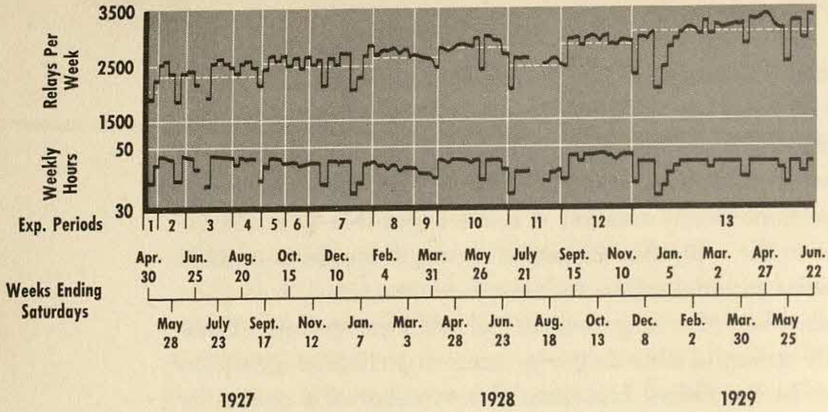


FIGURE 10.3. *Output record for one worker in the Relay Assembly Test Room. The lower curve shows the actual working hours during each period. These were shortened through the introduction of rest periods, shortening the work day and the work week. In period 12, the original 48-hour week was put back into effect. The curves show that output rose independently of the experimental changes. (After Roethlisberger, F. J., and Dickson, W. J.,* Management and the worker. *Cambridge, Mass.: Harvard Univ. Press, 1939)*

room over a long period of time. The task of these women workers was the assembly of small relays. This task was selected because it was simple, highly repetitive (approximately 500 relays were assembled per day), required no machinery, and permitted accurate measurement of production. In addition to extensive individual daily production records of the number of relays assembled, a complete daily history, including comments of the six operators, was kept to give an accurate account of what happened when changes were introduced. The experiment had thirteen distinct periods. In period 1 production was measured while the employees were in their regular department; period 2 involved performance in the test room, and lasted 5 weeks. The other periods, varying from 4 to 36 weeks in length, introduced a pay incentive system, different frequencies and lengths of rest periods, and different lengths of the work week.

The data revealed two important facts: (1) Production increased dramatically from less than 2,400 to more than 3,000 relays assembled per day; and (2) there was no apparent relationship between these increases and the changes in the work environment. Production continued upward *regardless* of the changes. Figure 10.3 shows the record for one worker during a three-year period.

One possible explanation was thought to be the change in the wage incentive introduced in period 3. These girls were paid according to the productivity of the group, whereas in the shop they were paid on the basis of the total production of about 100 operators. To check this point, two additional experiments were run. A second relay-assembly group was set up, but kept in their regular environment in the shop. However, they were paid on a piece-rate calculated from the production of their own group. Another small group, a mica-splitting group, were put in a separate room where the conditions were identical to the original relay assembly room. However, the pay rate was still determined from the productivity of the entire shop. The results showed the second relay room increased production 12 percent and the mica-splitting room increased 15 percent. Since the original relay assembly room group had increased production 30 percent, the increase could not be attributed to the incentive system alone. The best interpretation of the original relay room results appears to be the changes *accidentally* introduced in the social aspects of the work situation. This was borne out by the observational data showing the increased friendships among the girls, as well as their comments about the work, the company, and their supervisor. This latter factor was regarded as especially important. Apparently the girls came to perceive the test room observer as a friendly supervisor in contrast to one that "bawled them out." Absenteeism and grievances among these workers also dropped off markedly.

This demonstration of the importance of factors in the social group in increasing productivity led the management of the company to undertake a mass-interviewing program involving over 20,000 interviews with employees and supervisors. From such interviews, other social factors of importance to performance were discovered. It was found, for example, that complaints frequently centered around an employee's social position in his work group. Attitudes toward such factors as wages, hours, and working conditions varied according to the employee's social position, attitudes of his group, and his relationships with others. To pursue these findings a further study was carried out with a team of 14 experienced male operators wiring "banks" of relays. Nine of the men wired electrical connections, three of them soldered the connections, and two of them inspected the finished connections. Three wiremen and one solderman typically worked together in a team. One of the first findings in this "bank wiring room" was that the wage incentive system was *not* motivating the workers to produce more. The workers in the group defined a day's work as the wiring of two units and they either paced themselves accordingly or stopped before quitting time.

In this group, the rules set by the company were clearly replaced by those set by the group. What influenced the behavior of individuals were the group's rules and not those of the management. Individuals regularly traded jobs. Three men always reported more work than they produced, two always reported less, and the others varied their reports according to circumstances. The standard of production was really the group standard rather than that set by the company's time-study engineers. Men who turned out too much were called "rate busters"; men who turned out too

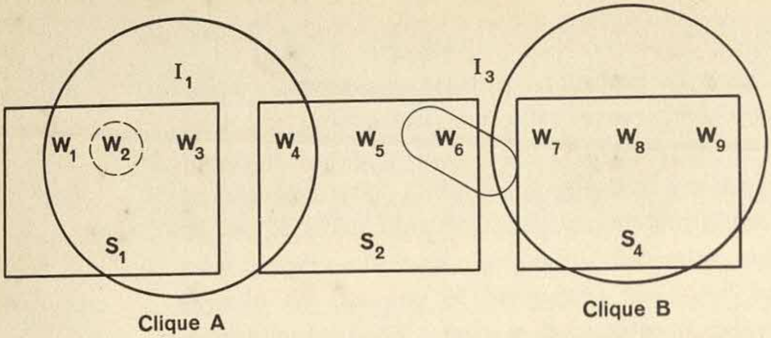


FIGURE 10.4. *The internal organization of the bank wiring room. (W = wireman, S = solderman, I = inspector). There were two main cliques among the three "formal" .teams. (After Roethlisberger, F. J., and Dickson, W. J.,* Management and the Worker. *Cambridge, Mass.: Harvard Univ. Press, 1939)*

little were "chiselers"; men who told a supervisor anything reflecting on an associate were "squealers." Rate busters, chiselers, and squealers were controlled by an authority system which included ridicule, sarcasm, and "binging" (a hard blow on the upper arm). The rules were such that anyone "binged" never protested, but was allowed to "bing" back.

The group chief chose to accept much of this conduct in order to gain the good will of his men. In fact, when a new group chief was assigned, who placed greater stress on conduct and efficiency, no increases in productivity occured. Actually, the first group chief with his leniency received more cooperation than the second supervisor.

It was found that the men organized into two clearly defined subgroups or cliques. Group 1 consisted of four wiremen, a solderman, and an inspector, and considered themselves the superior group. The second group, not as well organized, consisted simply of one solderman and three to five wiremen. The third solderman and the other inspector were "isolates"; that is, they were not in either group. Figure 10.4 diagrams these relationships. These cliques functioned in many kinds of group situations including playing games, job trading, friendships, and helping one another. One of the strongest influences on the behavior of the individuals was the fear of losing status in one of the cliques.

Status relationships within the group were noted. The wiremen represented the "elite," even though their pay was the same as that of other men. The wiremen occupied a social position above the soldermen; generally they originated job trading with soldermen, but the reverse did not occur. Status was differentiated by dress. The foremen and assistant foremen wore coats and vests, the section chiefs wore vests but no coats. The other men wore neither coats nor vests.

The findings in the bank wiring room illustrate many of the characteristics of social structure which we have discussed previously. Aside from the intricate social structures identified, the main finding in the bank wiring room was that the existence of social structures may *restrict* productivity. Coupled with the studies in the relay assembly room, where group influences *facilitated* productivity, this research provided many significant leads to the understanding of the effects of group membership on performance.

Group Norms

One of the basic ways in which groups influence individuals is in the development of *group norms.* The results obtained in the relay assembly room and the bank wiring room illustrate this very well. A *group norm* is *a standard of behavior approved by the group and enforced upon members by mutual pressure.* The operation of this principle is a basic characteristic of groups, and is the major reason why a group is really "different from the sum of its parts." For example, a person in a picket line does things he would not do as an individual. He may throw bricks, abuse fellow workers and policemen, and act in other ways which reflect differences from his behavior as an individual. Members of large fraternal orders do things at conventions they would consider ridiculous elsewhere. Adolescents often dress in ways that adults deplore, but which seem perfectly appropriate to them in terms of their group norms.

The operation of norms is often very subtle, and the individuals involved are frequently not aware of their operation. An interesting experimental study on group influence was carried out using the simplest of stimuli.[4] When an individual is placed in a dark room and looks at a fixed point of light, he will soon see the light as moving. This is called the "autokinetic phenomenon." Objectively, the light does not move, but in complete darkness it appears to move, through different distances for different individuals. In this particular study individuals who consistently "saw" the light move short distances (about 3 inches) were placed (one at a time) in a dark room with two people who saw longer movements (about 9 inches). Each person stated aloud his estimate of the distance the light moved. It was found in this study that individuals tend to modify their judgments in the direction of the majority judgment, and further that they stick to this new norm for as long as a year even in the absence of other group members. Other experiments along these lines have used opinions on social issues, and have found similar shifts in individual attitudes, even in the face of objective evidence.

The influences of group norms are all around us. For example, medical students quickly learn to oppose federal health insurance plans; the college student who becomes a factory foreman learns to change his method of dress. Group norms are enforced by rewards, such as praise, increases in status, and raises in pay, and by punishments such as scolding, ridicule, or even ejection from the group.

INTERPERSONAL RELATIONS IN GROUPS

We now turn to a more detailed look at the nature of groups themselves, as well as the relations that occur between individuals within groups.

The Description of Groups

There are many ways of describing groups. One of the most obvious is to identify the group's function, as in "bomber crew," "surveying team," or "relay assembly group." But how can we describe how "bomber crews" or any other type groups differ from one another? It would be useful if we had a common set of characteristics by which we would compare different groups having different functions (for example, a bomber crew with Lodge 22 of the Royal Order of Muskrats). One system of characterizing groups has been developed, containing fourteen characteristics in which all groups may be said to differ. This provides a convenient way of thinking about groups and their effects on behavior.[5]

One set of characteristics pertain to the kinds of personal interactions that go on within a group. Groups differ in *intimacy*, the degree to which members of a group are mutually acquainted with one another and are familiar with the personal details of one another's lives. This characteristic is reflected in the nature of topics discussed by members, in modes of greeting, forms of address, and in the type of knowledge each member has about other members of the group. Groups also differ in *homogeneity*, the degree to which members of a group are similar with respect to social characteristics. It may be estimated by the relative uniformity of members with respect to age, sex, race, socio-economic status, interests, attitudes, and habit. A third characteristic is called *hedonic tone*, the degree to which group membership is accompanied by a general feeling of pleasantness or agreeableness. This factor is reflected in the frequency of laughter, conviviality, pleasant anticipation of group meetings, and in the absence of griping and complaining. In addition to these, perhaps the most obvious dimension of groups is *size*, or the number of people in the group. The size of the group has an obvious relation to the kinds of personal interaction possible within it.

Another set of group characteristics is related to the social structure that affects the behavior of the individuals within the group. Groups differ in *autonomy*, or the degree to which group members function independently of other groups. The degree to which a group determines its own activities provides a clue to its autonomy. A typical work group certainly has less autonomy than a social club, but work groups also differ markedly from one another in their autonomy. Related dimensions are those of *control* and *flexibility*. Control is the degree to which a group regulates the behavior of individuals while they are functioning as group members; a group in which members are afraid to express their opinions or deviate in their behavior is high in control. Flexibility is the degree to which a group's activities are marked by informal procedures rather than by adherence to established procedures. The roles of members of more flexible groups are free from specification through customs, tradition, rules, codes and other prescribed ways of behavior. Groups also differ in *stratification,* the degree to which a group orders its members into status hierarchies. This is shown in differences in the way that power, privileges, and obligations are distributed among group members. We saw previously that the bank wiring group was more stratified than the relay assembly group. A final characteristic pertaining to group structuring has been termed *permeability*. As the name implies, this is the degree to which a group permits ready access to membership. It is reflected in absence of entrance requirements of various kinds, and in the degree to which membership is solicited. Contrast, for example, the permeability of the local Democratic or Republican party with the country club and college fraternity.

Finally, a number of group characteristics relate to the group's orientation and striving for specific goals. These characteristics come close to what many people mean by "morale." One of these characteristics is *polarization*. This is the degree to which a group is oriented toward and works toward a single goal that is clear to the members and shared by them. Examples of highly polarized groups are combat units and "underground" resistance movements. *Cohesiveness* is the degree to which members of a group function as a unit. Even with shared goals, groups may differ in the amount of dissension and personal conflict among members, and in ability to resist disrupting forces. *Participation,* about which we will say more, is an important element here. This is the degree to which members of a group apply time and effort to group activities, and is shown by the number and kinds of duties members perform, by voluntary assumption of non-assigned duties, and by the amount of time spent in group activities. Two final characteristics are *potency* and *stability*. Potency means the degree to which the individual's needs are satisfied by membership in the group itself. Aside from other goals such as winning basketball games or surviving battle, the group itself may or may not be important to the individual. If a member feels honored or gains social status by belonging, the group has high potency for him. Some individuals may spend most of their waking hours working

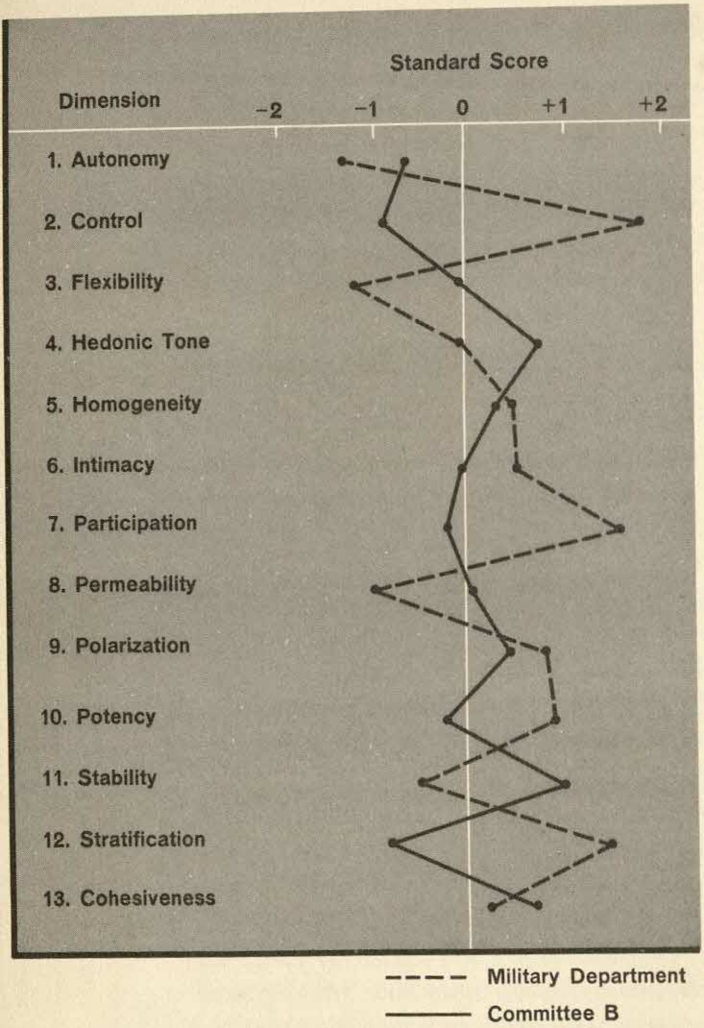


FIGURE 10.5. Comparison of two groups on fourteen "group dimensions." Both groups are in the same university. (From Hemphill, J. K., and Westie, C. M., The measurement of group dimensions. J. Psychol., 1950, 29, 325-342)

for the success of a particular group. The *stability* of a group is the degree to which it persists over time with essentially the same characteristics. This characteristic is indicated by rate of membership turnover, by frequency of reorganization, and by constancy of group size. One of the most unstable groups is the "mob"; one of the most stable is the family.

Questionnaires have been developed by means of which individuals can describe their groups along the fourteen dimensions we have outlined. Figure 10.5 shows a "profile" of two groups within a large university compared on these characteristics. It can be seen that the military department is higher in stratification and control over staff members, and lower in autonomy and flexibility than is the college faculty committee.

Formal and Informal Groups

The characteristics which we have described apply to both formal and informal groups. A *formal group* is organized and designed by someone who spells out the position, duties, and roles of group members. Its parts are labeled, and its stratification clearly indicated. Formal groups are often depicted by organizational charts, which are used in business, government, and military organizations. Social groups also may have charters which spell out the duties of members, the formal offices, and the chain of command.

It is generally recognized that the actual interactions that go on between individuals in formal groups do not conform exactly to these specifications. Instead, the *informal group* develops from first-hand experience. Thus, we find informal groups developing and existing *within* formal groups, as was exemplified by the cliques formed in the bank wiring room. Sometimes informal groups form in the absence of any formal grouping as is the case with street-corner gangs. However formed, such groups can be described by the same characteristics we described in the previous section. Informal groups are the ones which exert the greatest influence on individual behavior.

One technique developed to study the structure of informal groups is the *sociogram*.[6] To construct a sociogram each member of a group may be asked "Which person would you most like to have for a fellow worker (or partner, roommate, leader)?" and "Which person would you least like to have for a fellow worker (or partner, roommate, leader)?" From these responses a diagram like the one in Figure 10.6 may be constructed. This sociogram, which in this case includes only positive choices, describes the informal social structure of a fourth-grade class.

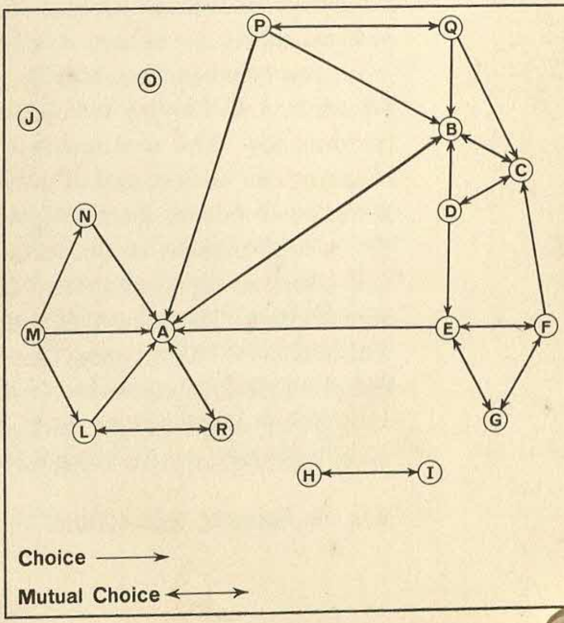
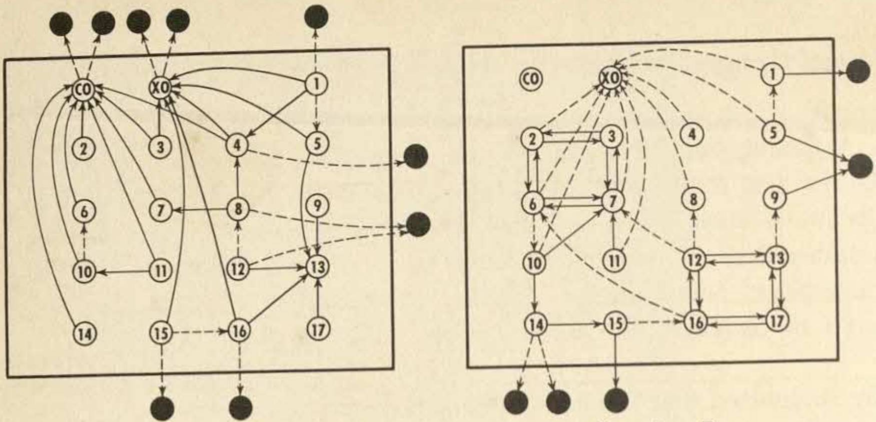


FIGURE 10.6. *A sociogram of a fourth-grade class. This sociogram shows that there are two main cliques, with individuals* A *and* B *the informal leaders. (After Thorndike, R. L., and Hagen, Elizabeth,* Measurement and evaluation in psychology and education. *New York: Wiley, 1955)*



Squadron A **Squadron B**

FIGURE 10.7. Sociograms of two flight squadrons. Solid lines are positive choices; dotted lines are negative choices; the filled-in circles are individuals outside the squadron. In squadron A, the leaders receive many positive choices; in squadron B, the commanding officer (CO) is an isolate, and the Executive officer (XO) is rejected by group members. For additional explanation, see text. (After Jenkins, J. G., Nominating technique as a method of evaluating air group morale, J. Aviat. Med., 1948, 19, 12-19)

We see that A and B are the most sought-after members of the group (called "stars") and consequently occupy informal leadership positions. Pupils J and O did not choose anyone and are not chosen. They are "isolates." H and I, except for their mutual choice of each other, are also "isolates." Pupils P, Q, M, and N are fringe members; they do not really belong to any of the group but do choose members in the group. It can also be seen that there are two cliques, with A a member of both.

Figure 10.7 shows the sociometric technique applied to two Naval Air Force fighter squadrons. Squadron A has a high proportion of positive choices inside the group, especially of the leaders. Squadron B has a larger proportion of negative choices of leaders, and many of the positive choices of its members are of men in *other* squadrons. Note also the cliques which have developed in Squadron B. As might be suspected, it was found that Squadron A had higher morale and was a more effective unit in terms of its performance. The sociometric analysis also indicated the desirability of changing the leaders, and of transferring certain individuals from Squadron B and other individuals into Squadron B.

A final example of this technique provides a comparison of the formal and informal organization of a larger group; in this case, a small military organization. The investigator asked each individual to name the people with whom he had the most direct business. It may be noted in Figure 10.8 that the executive officer receives the most frequent mention, in accordance with policy about going "through channels." It is also clear that Department 1 conforms in its behavior to what is specified in the organizational

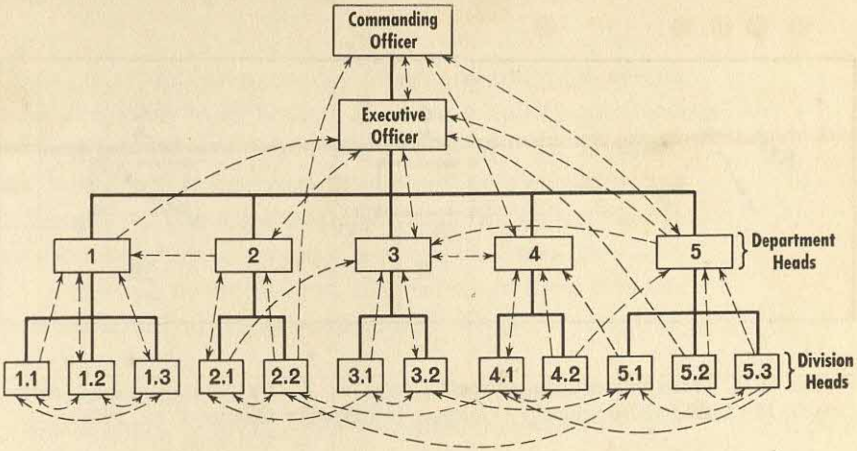


FIGURE 10.8. *The formal and informal organization of a military organization. The arrows indicate the persons with whom each individual spent the most time on business matters. (After Stogdill, R. M., The sociometry of working relationships in formal organizations,* Sociometry, *1949, 12, 276-286)*

chart. However, the other departments show marked deviations. Division Head 2.2 frequently bypasses the two levels above him and Division Head 4.2 frequently works with a department head other than his own. The grouping indicated by the dotted lines is really the functioning group.

Sociometric methods have been used in industry to fit work teams together. One study evaluated such an attempt with 74 carpenters and bricklayers on a housing project.[7] Workers were allowed to pick their partners and these in turn picked other groups of two to form four-man work-teams. Twenty workers were assigned their first choices, 28 had their second choices, and 16 obtained their third choices. Eight of the 74 were isolates, but were also assigned individually to one or another group. The results showed a drop in turnover from an average of 3.11 quits per month to .27; labor cost per unit dropped from $36.7 to $32.2. Other industrial examples show the effectiveness of this technique. The military services also have used sociometric methods in the assembly of crews and combat teams.

Communication and Group Functioning

The sociogram and related techniques give us a picture of the interrelationships of people within a group. They provide information about the "communication network" of a group and the positions of influence in a group. Obviously, the individual who cannot or does not communicate with anyone does not influence others in the group. The individual with the most influence is likely to be the one that knows what's going on and, in turn, provides relevant information to others. Accordingly, the question arises as to what is the "best" communication network, for the most efficient

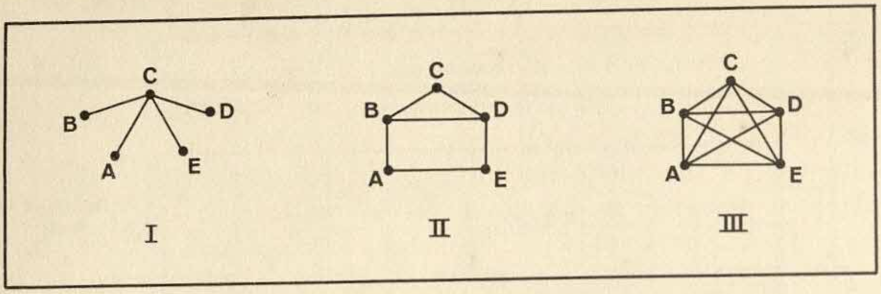


FIGURE 10.9. *Three different communication networks. See text for explanation. (After Leavitt, H.,* Managerial psychology. *Chicago: University of Chicago Press, 1958)*

group functioning. While comprehensive answers to this question cannot yet be given, the results of a number of research studies provide some consistent indications.[8]

To illustrate what is meant by "communication networks," we may consider the three different five-man groups shown in Figure 10.9. In the first case we have a staff in which everyone answers directly to individual C. There is no communication between the other individuals, but individual C can channel the information to all members. In the second system, every individual has at least two channels. If individual C is a supervisor, B and O may be his immediate subordinates. In the third system everybody talks to everybody else. Thus in system I individual A can talk to the supervisor directly. In system II he goes "through channels" to B although he can talk to E. In system III he can talk to anybody. There are many other possible arrangements. The question is, which system will be most effective for these five men?

One study compared network I with nework II in solving a problem by the group. Each man was given five solid-colored marbles of which one color was common to all men in the group. The group had the task of finding the one color which all five men had in common. They proceeded by writing notes to one another over the available channels, saying such things as "I have red, green, yellow, blue, and brown." Eventually they discovered that they all had red marbles in common. After playing this game several times, the groups got very fast at it. At this point, the marbles were changed. Instead of simple colors, they were given odd shades of color to describe. Now two men looking at identical marbles might describe them quite differently (for example, greenish blue *vs.* aqua). The engineer would say that "noise" has entered the system, under these conditions.

The finding of this study was that nework II adapts to this type of change quickly, whereas network I continues to make many errors. Other studies with these two networks, using more realistic industrial problems, have shown that for a given problem network I is faster, but that the morale of people in network II is likely to be higher. In network I all except C are likely to get bored and feel left out, while in network II all are involved. Network I imposes orderliness, but network II imposes more checks on the accuracy of the information. The important point made by such studies is that the *communication structure* of groups affects speed, errors, and flexibility of the group in meeting new problems. The nature of the communication structure acts upon individuals to make them feel more or less independent, more or less responsible.

The network of communication which functions best depends on the group's function. For example, in groups such as committees, where everyone's ideas may be worth something, networks like system II, in which everyone has access to approximately the same number of channels, are probably better than I. When the problem changes, anyone in the group using system II is in a position to exert leadership, while system I is more rigid in this respect. When one is interested mainly in getting started fast and in maintaining continued speed in a standard operation, network I appears to work better. One structure which sometimes causes problems is the one illustrated in Figure 10.10. Here the boss's assistant (B) is in a very powerful spot, and can be selective in what he transmits to and from the boss. Often the secretary to the president or a department head may assume this role.

Highly centralized groups whose communication structure is like network I may work faster on straightforward problems, but there is less self-correctiveness in the system when new and unusual problems come up.

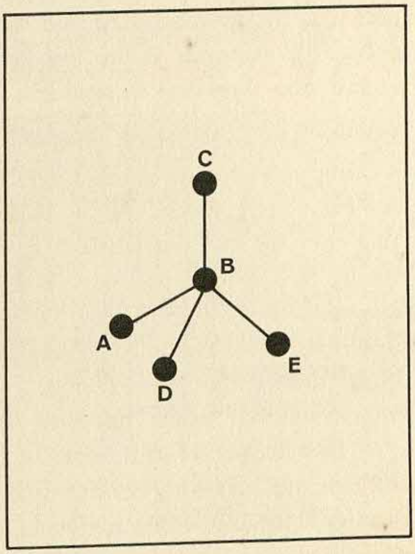


FIGURE 10.10. *A communication network in which B plays a central role.*

Similarly, creativity of the group may be higher with network II, in which each member has more than one source of information. Some of these experimental findings, of course, conflict with traditional formal organization charts. While there are many questions yet to be answered, a number of clues to effective organization has been suggested by research on communication networks.

MORALE

Morale is a term frequently used to refer to the team "spirit" of a group, as in speaking of the high or low morale of a football team, an army, or an industrial work force. Morale is a group phenomenon, and not simply an average of individual attitudes. Thus, a few workers who are respected by their fellow workers may lower the morale of the entire group, even though other factors contributing to their individual satisfactions are present. Conversely, a skilled leader may raise the morale of the entire group.

The group character of morale is illustrated by the case in which a worker is discharged. If he is a person who was liked by others in the group, the group's morale will likely go down. If he was disliked, the group's morale is likely to go up. There is the third possibility, that this worker was an "isolate" and not considered a part of the group. In this case his discharge will have little effect on morale.

Characteristics of Morale

A baseball team may have poor morale even though each inividual player is highly motivated and satisfied with his job. Such a situation can occur, for example, if the left fielder is motivated to achieve a home-run record, the shortstop to steal the most bases, the first baseman to lead the league in batting, and so on. This team may still lack a *goal common to the group*, which is essential for high morale. Another characteristic of morale is a *feeling of "togetherness"* among group members. This is evidenced by cooperative behavior on the part of group members. Further, the success or accomplishment of any one member is experienced as a gain for all.

Groups with high morale are apt to show *"staying qualities."* This means that members tend to persevere in the face of adversity, and are not as easily frustrated by failure.

The student will recognize that, in terms of our previous discussion, high morale groups are likely to be those high in cohesiveness, participation, potency, and stability. Under ordinary circumstances they are likely also to be high in hedonic tone.

Some Factors Influencing Morale

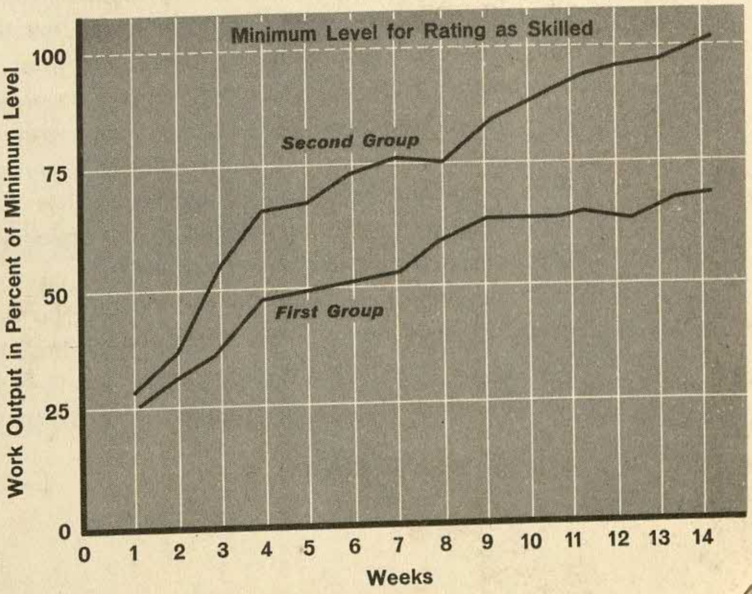
Much of what has been said about groups and their characteristics is relevant to the matter of improving morale. First of all, it is desirable to provide *opportunities for teamwork.* Some jobs lend themselves readily to this; with other jobs the opportunities are not so obvious. For example, it has been shown that sewing machine operators, performing isolated operations, become part of a team when they are allowed to participate in setting a production goal. In Chapter 4 we described a study in which girls sorted bills in a large room containing 100 workers. When the girls were placed in groups of 10, higher morale resulted, even though the operations performed were the same.

Interactions among employees may be encouraged to improve morale. Although many companies actually discourage conversation by rules and regulations, there is no evidence that this is a desirable policy. Noise and other environmental conditions tend to inhibit conversation, but opportunities for interaction may be provided in many different ways.

Knowledge of progress appears to be an important condition related to morale. Figure 10.11 shows an example of this. One group of power machine operators was told the level of production they would have to reach in 14 weeks. Another group was told the final goal but was also given weekly goals, and thus had more immediate "feedback" of progress. The figure indicates the superiority of output for the second group.

Our previous discussion has also mentioned the importance of *stable*

FIGURE 10.11. *The effect of observable progress toward a goal. The first group of power-machine operators was told the final goal. The second group was told the final goal but was also given weekly goals. They had direct knowledge of progress each week. (After Watson, G. (Ed.),* Civilian morale. *Boston: Houghton Mifflin, 1942)*



groups. A group requires time to develop common goals, group norms, and other aspects of social organization. Keeping the group together is likely to increase the chances of achieving high morale.

The *type of reward system* in the plant cannot be overlooked. Individual pay incentive systems are likely to encourage competition and discourage teamwork. The group incentive plan, provided the employees accept it as fair and without suspicion, may stimulate rather than retard group effort.

Although a number of other factors determining morale could be mentioned, two deserve special consideration. The *type of leadership* influences morale. Since the leader typically occupies an influential position in the group, his behavior is an important determiner of group behavior. Related to the type of leadership is the opportunity for *participation* and need satisfaction provided other group members. We shall turn next to a consideration of these important topics.

LEADERSHIP

At one time leadership was thought of as a personality trait, or as a combination of personality traits possessed by some people and not by others. To select leaders, it was considered necessary only to find those individuals who possessed this trait in well-developed form. Thus, the goal of early research was to discover those specific traits which distinguished leaders from followers. This research led to a long list of traits which characterized leaders. However, the main conclusion was that traits which described leaders in one situation did not necessarily apply to those in another.[9] If the student will think for a moment of specific individuals he considers effective leaders (in politics, education, athletics, or any other field), he will probably consider this conclusion an obvious one.

Subsequent research findings showed that the particular group situation was highly important in determining what kind of leadership would be effective in it. This led to the conception of leadership as a relationship between an individual and a group. Leadership is no longer thought of as a trait that someone "has," but rather as a particular type of performance that certain individuals may engage in. More specifically, leadership may be defined as the *act of influencing the activities of others in a group toward goal-setting and goal-achievement.*

The important points in this definition are that leadership is (a) a group phenomenon, (b) a way of acting, and (c) a matter of influencing others. By this definition the existence of leadership can be demonstrated only by what others in the group do. In industry, for example, people are placed in supervisory jobs because there is more work than one man can do. The supervisor's job is to create conditions within which he can get others to help get the job done. By definition, if the supervisor's own behavior does not facilitate getting the work done by the other members of his group, he is not a leader.

This view of leadership allows for the fact that certain supervisors may influence their groups by allowing members to participate in decisions. In contrast, a supervisor who makes all the decisions and issues orders may be less effective, in terms of his influence upon the group's activities. The effectiveness of leadership, then, must be evaluated in terms of the effectiveness of the particular group, rather than in terms of a stereotyped list of traits.

This does not mean that traits play no part in leadership. Rather, it means that the situation determines which traits will, in practice, turn out to facilitate leadership. For example, in wartime or in similar times of stress, a nation may turn to a strong, aggressive leader; during such periods such an individual may be seen as the best means of need satisfaction to other group members. In peacetime, when the goals have changed, such behavior is no longer seen as satisfying individual needs and goals, and may, in fact, be seen as threatening. A leader with such qualities may then be rejected in favor of another. This state of affairs may be partly responsible for Winston Churchill's change in status in England before, during, and immediately after World War II, as well as for the several changes in status of Charles de Gaulle in France.

Cultural factors are, of course, part of the situation. Supervisors in industry cannot treat their employees as they themselves may have been treated twenty years ago. There has been a great deal of social change regarding the prerogatives of managers and the role of employees in industry. Similarly, notions of leadership have changed as they pertain to parent-child and teacher-pupil relationships.

We do know, however, that some individuals are effective leaders in several different situations. One reason is that different situations may have a lot in common. Research has also revealed that, while many specific traits are not dependable indications of leadership, some very general traits are characteristic of leadership in various situations.[10] One of these has been called *social sensitivity*. This is the accuracy with which an individual perceives and understands another person's behavior and is sensitive to his needs. The other is *behavioral flexibility*, which characterizes the individual who is able to adapt his behavior to changing group needs and situations. The army top sergeant may or may not become a successful industrial foreman. However, if he possesses these two traits he is more likely to make the transfer from military to industrial leadership.

An Experiment on Leadership Influences

We are still left with the question of what patterns of supervisory behavior turn out to be, in practice, leadership behavior with particular groups. If we focus on behavior rather than traits we may gain some idea of an answer to this question.

A classic experiment on the relation between leadership and group performance was carried out with children.[11] Three styles of leadership labeled "autocratic," "democratic," and "laissez-faire" were tried out on hobby clubs made up of ten-year-old boys who met after school hours during a period of four months. Each of the four clubs that participated in the study consisted of five boys. The groups were matched in average intelligence, personality, and social behavior. Four adult leaders were trained to act according to these three different styles of leadership:

1. The *autocratic* leader named the club, decided on the activities, assigned the work and kept the boys busy.

2. The *democratic* leader used discussions to settle problems and made decisions with his group. Members divided the tasks among themselves and chose their work partners. The leader outlined general steps and group goals.

3. The *laissez-faire* leader let it be known he was available for help, but took no part otherwise after supplying the material used in hobby activities. He gave information when asked, but never volunteered it.

The leaders shifted from club to club every six weeks, each one changing his leadership style at the time of transition. Thus, each club experienced each leadership style under different leaders. The results showed the laissez-faire condition poorest in every respect. These groups accomplished least and were most dissatisfied with the club (even though they played more than they worked). The democratic condition was superior to the autocratic condition in that the democratic leader was more popular, there was less hostility, and more cooperation and originality were shown. There was also more interest in the activities of the club, and greater friendliness among the boys. They kept working when the leader left the room, whereas the boys under the other two conditions were glad to stop. In the autocratic groups production was higher, but only when the leader was present. Four boys dropped out of the study, all during the autocratic condition. The autocratic group showed more hostility toward each other and toward the leader, made more demands for attention, and frequently treated one of their members as a "scapegoat."

Whether or not these leadership patterns produce similar behavior in adults is not the main point. What is demonstrated by this study is the fact that the same individuals behave quite differently under different patterns of leadership. Further, productivity and morale of group members are influenced by these different forms of leadership. It may be said that the different leadership patterns produced different "social climates" within which the groups functioned.

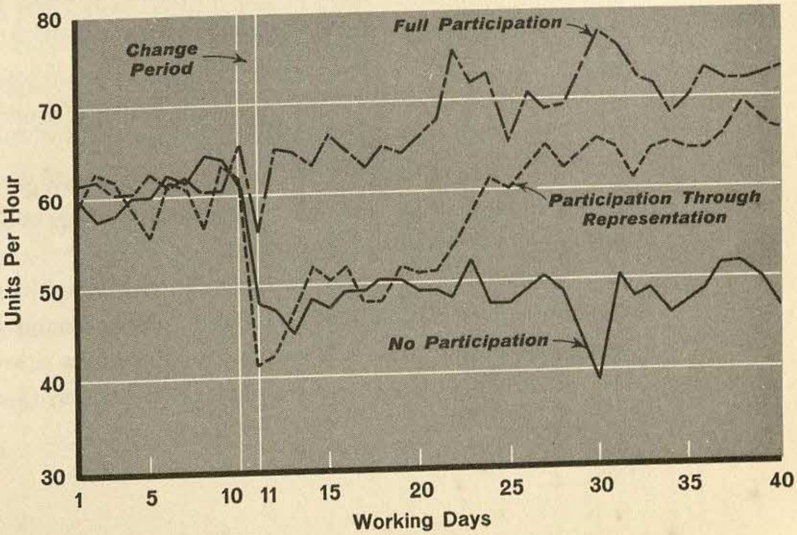
Group Decision and Leadership

There are some parallels between the experiment with children we have just described and some studies using adults which are mentioned in Chapter 4. There we pointed out that the social motives inherent in group participation were found to be effective in (a) changing the meat buying habits of housewives (b) changing baby feeding habits, and (c) setting production goals by employees.

Other examples of the effects of participation come from industrial studies. A persistent problem in industry is the necessity of changing work methods, either for competitive or technological reasons. Typically, these changes are made directly by management, and often there is employee resentment and a drop in productivity.

In one plant, a job change was required in the method of inspecting, folding, and packing pajamas. An experiment was conducted in which the change was made in one group of 13 workers in an autocratic fashion. A meeting was held and the management explained why the change was needed. A time-study man explained the new piece rate and answered questions. The workers were assured of the ease of the new job and told that a bonus arrangement would prevent them from losing money during the learning period. Two groups of 7 and 8 workers were handled more

FIGURE 10.12. *Group participation and productivity. The two groups given full participation showed similar curves and have been averaged here. (After Coch, L., and French, J. R. P., Jr., Overcoming resistance to change, Human relations, 1948, 1, 522)*



"democratically." The employees were presented with an account of the need for a change in the layout, and they worked with the time study man in planning the change. In a fourth group of 18, most members did not participate; the majority was represented by two employees, who participated with management in the change and discussed developments with the rest of the group.

Figure 10.12 shows that the group handled autocratically showed resistance at the outset; production dropped and never recovered to the old level. During the first 40 days, seventeen workers quit their jobs, and there was much aggressive behavior and an accumulation of grievances against the new rate. The groups with full participation did not show as marked a drop in productivity, showed a quick recovery, and attained higher productivity levels. The group with limited participation showed a marked drop and a slower recovery but eventually reached the output of the "democratic" group. When the autocratically handled group failed to recover, another change was made with their full participation; with this, they recovered to a new high level of production.

The effectiveness of the democratic approach and its use in a number of different industrial jobs does not mean that supervisors are giving up their prerogatives. There are many problems for which group decision is inappropriate. Even in cases where group decision is used, the area of freedom is usually clear and the supervisor still functions as an expert. One of the by-products of this behavior is that other decisions made by supervisors are more likely to be accepted and not regarded with suspicion. In other words, by adopting a particular leadership pattern, the leader may change the social "climate" in his work group.

Supervisory Behavior Patterns

The use of group decision is only one aspect of the leader-group relationship. What specific behavior patterns do supervisors engage in on the job? One approach to this problem listed over 1,800 specific behaviors that supervisors display. These were classified and sorted into ten categories which seemed to cover the range of supervisory activities.[12]

1. *Initiation* is the frequency with which a supervisor originates, facilitates, or resists new ideas or new practices.

2. *Representation* is the frequency with which a leader defends his group against attack, advances the interests of his group, and acts in behalf of his group with outside agencies.

3. *Fraternization* is the frequency with which a supervisor mixes with the group, stresses informal interaction between himself and members, or interchanges personal services with members.

4. *Organization* is the frequency with which the supervisor defines or

structures his own work, the work of other members, or the relationships among members in the performance of their work—acts which spell out duties and ways of getting things done.

5. *Domination* is the frequency with which the supervisor restricts the behavior of individuals or the group in their activities, decision making, or expression of opinion.

6. *Recognition* is the frequency with which a supervisor engages in behavior which expresses approval or disapproval of group members—actions which evaluate group members and deal with the distribution of rewards.

7. *Production emphasis* is the frequency with which the supervisor sets levels of effort or prods members for greater effort or achievement (oriented toward volume of work).

8. *Integration* is the frequency with which a supervisor tries to increase cooperation among group members, tries to reduce conflicts within the work group, or promotes individual adjustment to the group.

9. *Communication down* refers to the frequency with which the supervisor provides information to group members to increase understanding and knowledge about what is going on.

10. *Communication up* is the frequency with which the supervisor seeks information, and tries to keep informed about what is going on in the group.

These categories of leader behavior provide a convenient way of thinking about the complex variety of activities a supervisor may engage in. We can all think of different supervisors who show different "profiles" if rated on these categories.

For the purpose of determining frequencies of actual supervisory behavior patterns, questionnaires were developed by means of which behavior could be described in each of these ten categories. A typical "item" for *initiation* was:

"He tries out new ideas in the group."
always_____often_____occasionally_____seldom_____never_____

An item on *communication down* was:

"He calls the group together to discuss the work."
always_____often_____occasionally_____seldom_____never_____

In general, results of this questionnaire study showed that subordinates rate supervisors as showing "good" leadership when they are high on each category except *domination*. One of the main findings of these studies was the high degree of overlap in these patterns. Descriptions of supervisors in industry, in the Air Force and the Navy, in school systems (where teachers described the principal), and in colleges (where professors described department heads) showed high correlations among these patterns. For example, a supervisor high in *Organization* was likely to be high in *Initiation*. Through correlational studies, it was discovered that there were two broad basic patterns which accounted for much of what the supervisor did.[13] These were labeled *Consideration* and *Initiating Structure*.

Consideration includes behavior indicating friendship, mutual trust, respect, and a certain warmth between the supervisor and his group.

Initiating Structure includes behavior in which the leader organizes and defines the relationship between himself and members of the group. He defines the role he expects each member to assume, establishes channels of communication, and establishes ways of getting things done.

Table 10.2 gives examples of some specific performances diagnostic of these patterns. The important finding was that the two patterns were independent of each other; a supervisor can emphasize either or both patterns. These dimensions can be used as coordinate axes by means of which any supervisor's behavior can be located, as illustrated in Figure 10.13. Most supervisors have to play both roles, but in different degrees. These are not, as was once thought, opposite poles between which one must choose. Instead, the problem is usually one of finding the optimum balance between them. This kind of supervisory behavior, of course, is related to our previous discussion of social sensitivity and role flexibility. The supervisor high in these traits is sensitive to the changing needs of a particular group situation and should accordingly be better able to find this balance.

TABLE 10.2
ITEMS ILLUSTRATING LEADER BEHAVIOR PATTERNS

Consideration

- —He sees that a person is rewarded for a job well done.
- —He makes those in the group feel at ease when talking with him.
- —He refuses to give in when people disagree with him. (scored negatively)
- —He changes the duties of people without first talking it over with them. (scored negatively)
- —He backs up his men in their actions.

Initiating Structure

- —He offers new approaches to problems.
- —He asks for sacrifices for the good of the entire department.
- —He assigns people to particular tasks.
- —He criticizes poor work.
- —He encourages slow working people to greater effort.

(From Fleishman, E. A. The description of supervisory behavior. *Journal of Applied Psychology*, 1953, 37, 1-6.)

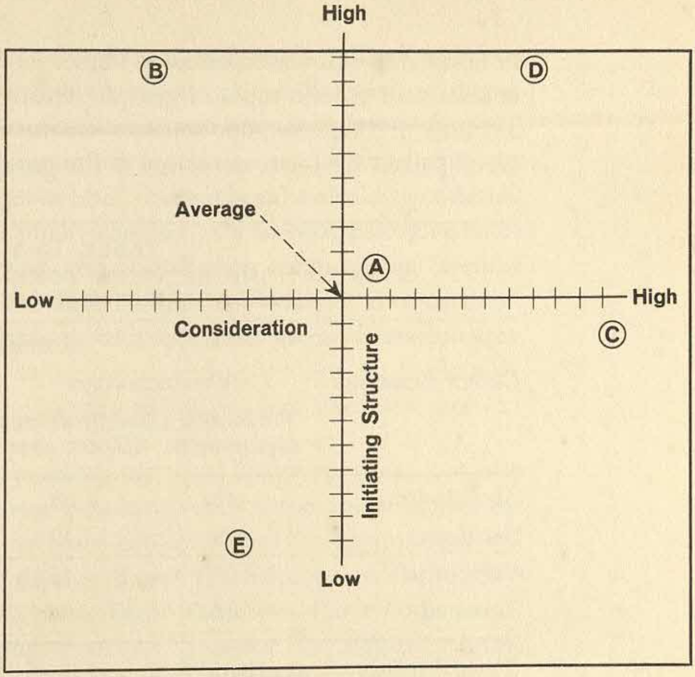


FIGURE 10.13. *Consideration and Initiating Structure as coordinate, independent axes. Supervisor A is about average on both dimensions. Supervisor D is high on both Consideration and Structure behavior. Supervisor C is high on Consideration and average on Structure. Supervisor B has a pattern which many would call "authoritarian." Supervisor E appears to operate in a "laissez-faire" manner and may not be exerting much "leadership." A particular supervisor's relative standing on these dimensions may be measured by means of questionnaires (see Table 10.2).*

Relationship between Supervisory Patterns and Group Behavior

The behavior of group members is related to the extent to which the supervisor emphasizes Consideration and Initiating Structure. For example, in bomber crews it was found that aircraft commanders high in Consideration behavior had crews with friendly relationships among the crew members themselves. It was also found that when commanders were low in both Consideration and Initiating Structure behavior, the crews tended to form cliques and to order themselves into status hierarchies. In terms of our discussion of groups, such crews were higher in "stratification."[14]

Industrial studies also indicate that foremen low in both Consideration and Initiating Structure may not be perceived by their own subordinates as the "boss." Thus, the organizational chart may indicate one thing, but the functional leadership may be quite different. Such supervisors may be bypassed by their own subordinates, who turn to another foreman, to someone higher up, or to an informal leader in their own work group.[15] Apparently, in bomber crews or industrial work groups, if the supervisor does not provide "leadership behavior," the group will organize its own informal leadership structure.

Consideration and Initiating Structure behavior of the supervisor is related to such group behavior as absenteeism, accidents, grievances, and turnover among group members. Table 10.3 summarizes some of these results for two types of operations in an industrial plant. The findings for production line foremen differ somewhat from non-production foremen (e.g., maintenance, services), emphasizing again the situational variables in leadership. However, foremen higher in Consideration behavior had less absenteeism in both types of groups. Among non-production foremen, high amounts of Consideration behavior on the part of the supervisor was also accompanied by fewer accidents in his group. Foremen who engaged in a great deal of Initiating Structure behavior had higher turnover in the non-production groups and more labor grievances in the production groups.

TABLE 10-3
CORRELATIONS BETWEEN FOREMAN BEHAVIOR AND GROUP BEHAVIOR ON THE JOB

GROUP BEHAVIOR	FOREMAN BEHAVIOR			
	CONSIDERATION		INITIATING STRUCTURE	
	Production departments	*Non-production departments*	*Production departments*	*Non-production departments*
Absenteeism	−.49	−.38	.27	.06
Accidents	−.06	−.42	.15	.18
Grievances	−.07	.15	.45	.23
Turnover	.13	.04	.06	.51

(From Fleishman, E. A., Harris, E. F., and Burtt, H. E. *Leadership and supervision in industry*, Columbus, Ohio: Bureau of Educational Research, Ohio State University, 1955.) A negative correlation indicates that a low degree of this foreman behavior was related to a high degree of this group behavior.

SUPERVISION AND PRODUCTIVITY. One of the most important indices of group behavior is productivity. Groups with high morale are likely to be more productive, but this is not always the case. Frequently, the supervisor must keep in mind both of these aspects of group behavior.

The "best" behavior pattern cannot be specified for all groups, for much depends on the situation, as we have seen. However, it does appear that low degrees of Consideration behavior *combined with* little Structure behavior is the worst pattern. Similarly, there is evidence that emphasis on either of these patterns to the exclusion of the other is likely to be less effective. Studies with such diverse groups as bomber crews and university faculties indicate that the most effective leaders (aircraft commanders and department heads, respectively,) were above average in both Consideration and Structure.[16,17]

Other evidence on the behavior of effective supervisors comes from studies of various companies and government agencies. For one thing, the more effective supervisors were found to play a "*differentiated role*."[18] They did not do the same work as their subordinates, but spent more time in supervisory activities. Morale was also highest where the supervisor performed broad, supportive functions such as planning on-the-job training, trying to obtain promotions for subordinates, and keeping them informed about policies. Differentiation of these duties, it can be seen, relates to either Consideration and Structure behavior, or to both.

It was also shown that high-producing supervisors *delegated authority* more than low-producing supervisors.[19] Supervisors with low-producing groups, on the other hand, did more checking up on workers, gave more frequent and detailed instructions, and limited their subordinates' freedom more. Apparently, allowing more freedom increases motivation to produce. Supervision that is too close interferes with important needs of subordinates.

Leadership Climate and Supervisory Behavior

If what the supervisor does influences what his group does, it is also true that the supervisor's behavior is influenced by those above him in the status hierarchy. Thus, he has multiple statuses within the organization and must play different roles in relation to these. His behavior on the job is a resultant of these multiple influences. Table 10.4 shows the average scores on Consideration and Initiating Structure behavior for different levels within a large organization. In each case, the individual expressed his attitudes about "how workers should be led." It can be seen that the foremen fall in between what the workers expect and what their own supervisors expect, and that their views are much closer to those of their supervisors.

TABLE 10.4
COMPARISON OF LEADERSHIP ATTITUDE SCORES OF WORKERS, FOREMEN, GENERAL FOREMEN, AND SUPERINTENDENTS

GROUP	CONSIDERATION *Mean score*	INITIATING STRUCTURE *Mean score*
13 Superintendents	52.6	55.5
30 General Foremen	53.2	53.6
122 Foremen	53.9	53.3
394 Workers	57.0	44.2

(From Fleishman, E. A. The measurement of leadership attitudes in industry. *Journal of Applied Psychology,* 1953, 37, 153-58.) Only the worker scores differ significantly from the foremen scores.

The potent influence of the supervisor's own boss was demonstrated in a study of foreman training at the International Harvester Company.[20] Most of these foremen had been sent to a supervisory training program held at the company's Central School in Chicago. The emphasis in the course was on "human relations" training, as well as on content related to such

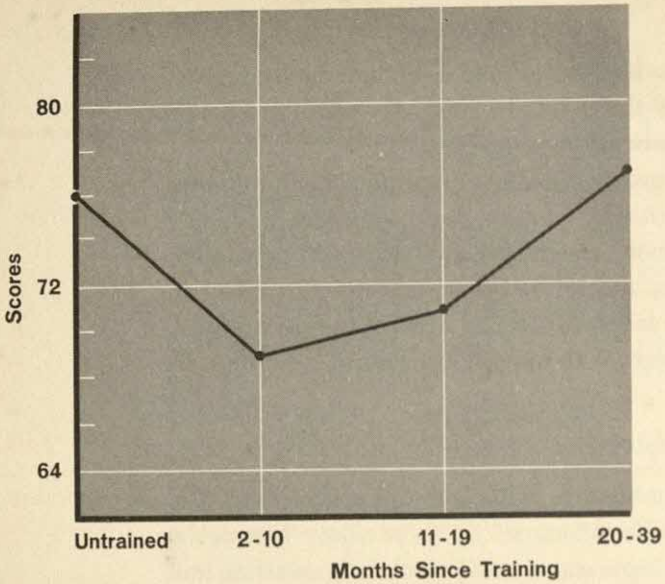


FIGURE 10.14. *Consideration behavior scores of untrained and trained foremen back on the job. (After Fleishman, E. A., Harris, E. F., and Burtt, H. E.,* Leadership and supervision in industry. *Columbus, Ohio: Bureau of Educational Research, Ohio State University, 1955)*

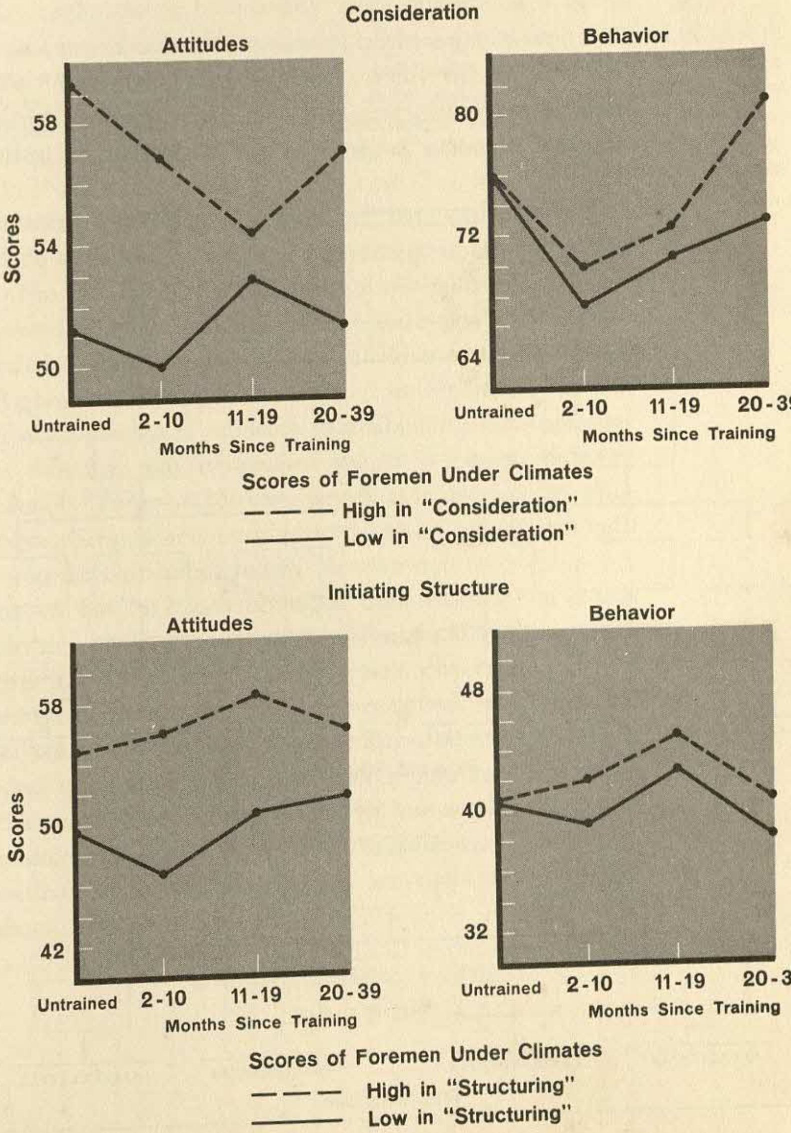
"structuring" activities as planning and organizing. The supervisors filled out attitude questionnaires before and after the course, which showed that during the course there was a shift for the group in the direction of higher Consideration and, unexpectedly, in the direction of lower Structure. However, it also appeared that the training affected different foremen differently.

But how do supervisors who have been through such training actually behave with their work groups when they return to the plant environment? Figure 10.14 compares four groups of foremen followed up over a period of 39 months. The general finding, shown in Figure 10.14, was that the effects of such training were not great in actually changing behavior back on the job, except for some initial *decrease* in Consideration behavior. This puzzling result was, of course, opposite to one of the objectives of the training. One reason for this turned out to be the influence of the "leadership climate" in the plant. By this we mean the behavior and attitudes of the foremen's own supervisors. It was found that those foremen who operated under a supervisor high in Consideration tended also to be more considerate of their own workers than did those foremen under supervisors lower in Consideration. Similarly, foremen who worked under supervisors high in Structure tended to perform in the same way with their subordinates. Figure 10.15 shows that this "chain reaction" effect of leadership climate is *more important* in determining the leadership behavior of the foreman than whether or not he has received formal supervisory training.

One more piece of evidence from the International Harvester Studies completes this picture. Supervisory personnel in this plant were asked to rate foremen on proficiency. The raters did not know the scores made by these foremen on Consideration and Structure. When these correlations were calculated it turned out that the foremen rated highest by their own supervisors in this plant were those described by their own workers as low in Consideration and high in Structure. Thus, the reward system in this plant emphasized one behavior pattern, while the central training school had emphasized another.

These findings are consistent with our previous discussion of social factors and the role of reward systems. What the supervisor really learns is what is rewarded in the particular social situation. In a very real sense he learns to behave in a certain way on the job according to the reinforce-

FIGURE 10.15. *Leadership attitudes and behavior of foremen operating under different "leadership climates" back in the plant. (After Fleishman, E. A., Harris, E. F., and Burtt, H. E.,* Leadership and supervision in industry. *Columbus, Ohio: Bureau of Educational Research, Ohio State University, 1955)*

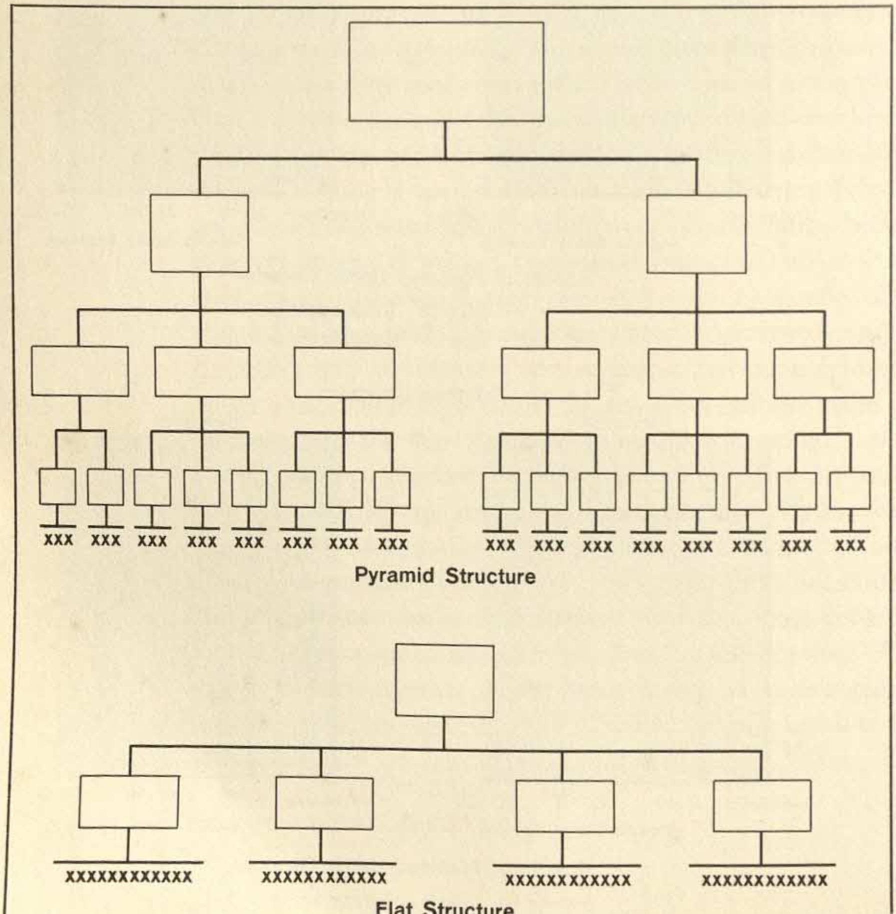


ments he receives there. In order to change his behavior on the job, attention has to be given to this social situation. One approach is to begin such supervisory training programs at top levels of management rather than at lower levels. This trend is very much in evidence today. Another trend is to involve the individual supervisor in longer training programs in which he is given increased opportunity to *practice* leadership skills which transfer to the job. Research has indicated that social behavior cannot easily be changed by typical lecture courses. We shall discuss some of the training techniques employed in Chapter 13.

ORGANIZATIONAL FACTORS

Companies are organized to achieve some goal or goals. These may

FIGURE 10.16. *Two types of organizational structures. Both organizations have 48 employees at the lowest level represented. The flat structure has only five supervisors at two levels of supervision, while the pyramid structure has twenty-five supervisors at five levels. These organizations are likely to differ in the effectiveness of communications, in freedom of action for individuals, and in supervisor-subordinate relationships.*



be to produce a product, make a profit, and provide satisfaction for certain human needs. Money, machines, and people are organized in certain ways to achieve these goals. Functions are divided up, roles assigned, patterns of relationships established. These patterns of relationships are the company's organization. In Figure 10.8 we saw an organizational chart showing the relationships set up by policy to achieve certain goals. As we have pointed out, the structural characteristics of an organization have an impact on the behavior of the people in it.

Often the way a company is organized forces the supervisor into ineffective methods. For example, if the first line supervisor is not delegated very much authority, he has very little freedom to employ effective methods with his own subordinates. Some companies are experimenting with "flat structures" in contrast to the traditional "pyramid structure." Figure 10.16 contrasts these structures. The essential difference is that the supervisors in the flat organization have many more subordinates under them and this results in fewer levels of supervision. One organization went from 15 different levels to four. The supervisor in the flat organization must, consequently, delegate more authority. Many companies are shifting to this form of organization by decentralizing, forming subunits with different managements.[21]

A second organizational problem is related to the emphasis on task specialization in modern technology. Roles in organizations are frequently assigned to minimize the number of skills a person uses in his job. Thus, a welder will weld, an assembler will assemble, etc. Not only are individual jobs specialized, but elements within jobs are often assigned to different people (e.g., tighten the 3 bolts on the left rear fender). There is little doubt that industrial efficiency requires specialization, but there are increasing indications that this may be pushed too far for many types of operations. In Chapter 4 (Figure 4.11) we saw that enlarging an individual's job can have beneficial effects on productivity and morale, through the increased control and motivation created in the worker.

Overspecialization of the functions of entire departments can occur. This may increase the size of each unit, which decreases the meaningfulness of the work to the individual, and requires closer supervision. Figure 10.17 shows two ways the same functions can be organized. The first plan has each function set up in a separate division. Thus, each can operate only in coordination with the other two. The second plan has each function represented within each division and each division a relatively independent unit. The point is not to do away with specialization, but rather that alternative plans may be investigated which serve the needs of the organization and of the employees as well.

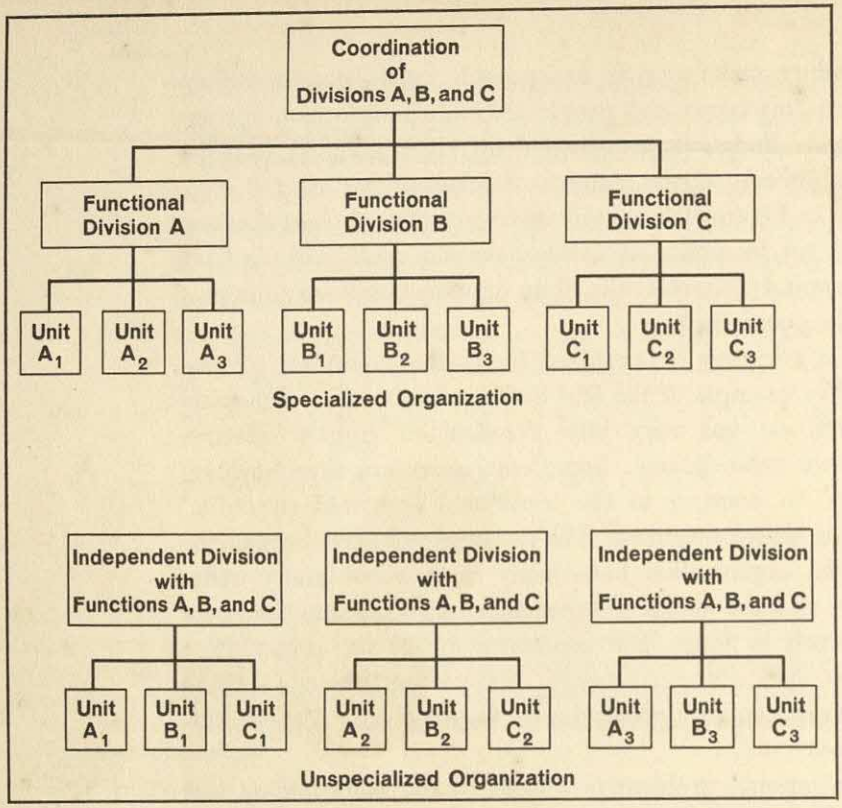


FIGURE 10.17. *Two ways of organizing the same functions. In the specialized division, none of the three divisions has any independence. In the unspecialized division, each division is a relatively independent administrative entity. (After Smith, H. C.,* Psychology of industrial behavior. *New York: McGraw-Hill, 1955)*

A third organizational problem is the need for effective communication. Adherence to chain of command may result in inefficient communication networks and lack of flexibility in an organization. A technique increasingly used by management makes use of committees consisting of representatives of different subgroups within the organization. Different committees are formed depending on the project and other circumstances. Essentially, this is a recognition by management of the lack of correspondence between the formal and functional relationships in the plant. It also makes use of the power of group decision we have described earlier. Further, it opens up two-way communication channels which facilitate problem-solving in the organization.

ATTITUDES

It is apparent from our discussion of social behavior that the interaction of people and groups is controlled by concepts. The kinds of con-

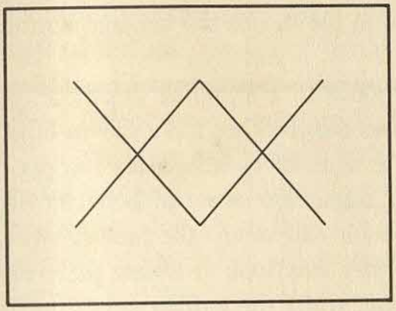


FIGURE 10.18. *A physical stimulus which is experienced differently by different individuals.*

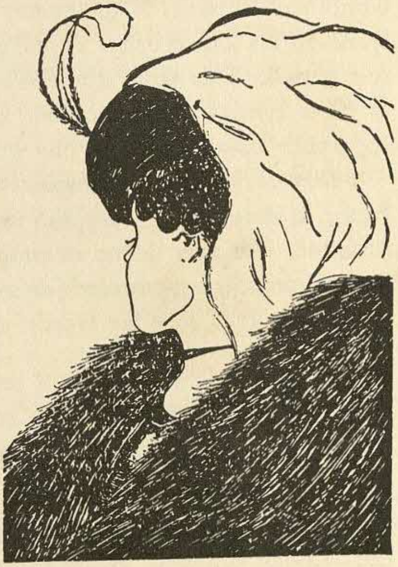


FIGURE 10.19. *The old woman and the young girl. Which do you see?*

cepts which affect an individual's behavior toward other people are called *attitudes.* Let us take a closer look at attitudes and how they are measured.

First, the same physical stimulus may be experienced quite differently by different individuals. An oversimplified illustration is given in Figure 10.18. If we ask a class to write down what is represented, most may say "two adjacent 'X s'." Others will say a "'W' resting on an 'M'." A few may hold out for a diamond with whiskers at each side. Of course, it is easy to switch from one "experience" to another once we hear of the other identifications. The important thing is that the external physical stimulus is the same for everyone.

Most situations are not this trivial or ambiguous. However, we may go one step further and examine Figure 10.19. Some will see a picture of an old woman, others will see a picture of a young, attractive girl. If students are first shown only the picture of the young girl, they do not see the old woman when shown the ambiguous figure later. Students first shown a picture of the old woman do not see the young girl. When told of the other possibility they may then be able to see it, but the original figure usually predominates.

The behavior of an individual in response to a stimulus depends on how he *experiences* the stimulus. In previous chapters we have shown how the previous learning of concepts as well as of motives influences the perception of a new situation. Applied to our discussion of social behavior, it may be said that the factory owner and worker experience the factory situation in quite different ways. The plant owner may look at a new piece of equipment in terms of the money it cost him, while the worker sees it as a threat to his job security. A bell signal in the plant may signal the time for rest pauses. This same stimulus may be seen as a symbol of regimentation or as a symbol for relaxation. Similarly, the same criticism made by a supervisor may be seen by one worker as helpful and by another as hostile.

In each of these examples, the individual's attitude is the important factor in determining how the individual will experience a given stimulus situation. We may define *attitude* as *an acquired predisposition to react in a characteristic way toward (or away) from some object, concept, situation, or person.* It is, in other words, an orientation, a readiness to respond.

Attitudes and Opinions

Opinions are more specific than attitudes. For example, we may ask a worker, "What do you think of the incentive system in this plant?" The answer is his opinion, whereas his attitude is his more general concept of the working situation. If the attitude is known, a variety of specific opinions can be predicted. If this worker has an unfavorable attitude toward the company, one may predict his responses to a suggestion system or a change in work layout as well as his response to the incentive pay plan. This, of course, underlines the importance of day-to-day encouragement of general attitudes, and the importance of the "social climate." If changes in attitudes occur, many opinions will change.

Let us take a further example.[22] What concept develops when you consider the following five words?

glass
bottles
alcohol
conversation
men in white jackets

Stop and think about this for a moment!

Suppose to this list we add the word "cat." After some hesitation this can readily be fitted into the above "picture." To complete the picture, let us add the items: test tube, bunsen burner, microscope. Immediately, we get a different concept of the situation; we now have a laboratory instead of a bar. A new attitude has developed. Each of the specific items changes (e.g., the bottles change shape, the conversation "sounds" different).

Sometimes we are not immediately aware of the influence of our attitudes on specific opinions. In one experiment students were ranked on their preference for 16 authors (e.g., Conrad, Barrie, Hardy, Whitman, and others). Later they were given 16 mimeographed passages all actually written by Stevenson, but each ascribed to a different one of these 16 authors. In no case did the students suspect this. When they were asked to rank these passages in order of merit, these rankings correlated significantly with their previous rankings of the assumed authors. Students tended to rank those passages ascribed to preferred authors higher than those ascribed to non-preferred authors. Each individual had a certain "readiness to respond" toward the individual stimuli, represented by the author's name.[23]

Attitudes and Prejudice

The basis of prejudice is readily seen in this discussion of attitudes. The man with an anti-Semitic attitude has a "readiness to respond" to certain supposed facts regardless of actual ones. Thus, if Mr. Miller, who is a Jew, lives in a Jewish section of town it is because "Jews are so clannish"; if he moves to a non-Jewish neighborhood it is because "They try to horn in everywhere." If Mr. Miller is strange in his habits this shows "Jews don't assimilate"; if he is indistinguishable in his habits "He is trying to pass himself off."[24] The presence of such attitudes allows the individual to reconcile contradictory opinions. For example, an anti-Semitic attitude allowed Hitler to brand Jews as capitalistic at one time and Communistic at another. Attitudes that the Negro race is inferior allows one to attack Negroes as "less clean" and then to employ them in subservient roles, as cooks and nursemaids in one's home.

Measurement of Attitudes

The simplest way to measure attitudes is to count the number of people for or against something. The limitation in this method is that it does not measure the *degree* of feeling for any one individual, but measures only the *direction* of the attitude. This may be appropriate for surveys of groups such as are undertaken in election polls, because such polls usually deal with specific opinions, rather than with attitudes.

A procedure for measuring the strength of attitudes in the individual is the *attitude scale.* Psychologists have developed several types of such scales, but we shall illustrate two. In one of the best-known methods, after the attitude to be measured has been defined, (e.g., attitudes toward war, toward birth control, toward the company), a large number of statements relevant to the issue are collected. Actually, these statements cover a wide range of specific opinions. The next step is to place the statements on cards, one to a card, and present them to a large number of judges, perhaps a hundred or more. Each judge is asked to sort these statements into an odd number of piles, usually eleven. These piles represent a scale ranging from an extremely favorable attitude toward something to an extremely unfavorable attitude. All items in the extremely unfavorable pile are assigned a scale value of zero, all those in the most favorable pile a scale value of ten, with corresponding values in between (a value of 5 for the middle pile would be neutral). The judges may not agree on the pile they assign certain items. These are then considered ambiguous and discarded. The final list of items may consist of 40 or less of the least ambiguous items, best representing points on this scale. Items can be selected which are "equidistant" in scale values. The final scale arrived at experimentally in this way may then be applied to other individuals whose attitudes we want to measure.

Table 10.5 shows part of a scale developed to measure employee attitudes toward their company. The employee checks those items representing his opinions and his attitude score is the numerical average of the items checked.

TABLE 10.5
SOME STATEMENTS USED TO MEASURE ATTITUDES OF EMPLOYEES TOWARD THEIR COMPANY

Scale value	Statement
10.4	I think this company treats its employees better than any other company does.
9.3	They don't play favorites in this company.
7.4	On the whole, the company treats us about as well as we deserve.
5.1	The workers put as much over on the company as the company puts over on them.
3.2	I believe many good suggestions are killed by the bosses.
1.5	In the long run this company will "put it over" on you.
0.8	An honest man fails in this company.

(After Uhrbrock, R. S. Attitudes of 4,430 employees. *Journal of Social Psychology*, 1934, 5, 365-377.)

Another type of scale requires the subject to place a check mark on a five-point scale placed below a number of statements relevant to the issue.

One end of the scale is labeled "strongly agree" and the other end "strongly disagree." Other alternatives of this type may be used. An example of several items from a scale developed to measure supervisory attitudes toward leadership is shown in Table 10.6.

TABLE 10.6
SOME ITEMS FROM A MEASURE OF LEADERSHIP ATTITUDES

Refuse to compromise a point:

always	often	occasionally	seldom	never
(0)	(1)	(2)	(3)	(4)

Back up what people under you do:

always	often	occasionally	seldom	never
(4)	(3)	(2)	(1)	(0)

Treat all people in the work group as your equal:

always	often	occasionally	seldom	never
(4)	(3)	(2)	(1)	(0)

(After Fleishman, E. A. *The Leadership Opinion Questionnaire,* in Stogdill, R. M. and Coons, A. E. *Leader behavior: its description and measurement.* Columbus, Ohio: Bureau of Business Research, Ohio State Univ., 1957.) These items are from the *Consideration* attitude scale. The numbers in parentheses do not appear on the form; these are the values which are added up to give a supervisor's consideration attitude score.

A person's attitude score is the sum of the scale values he has checked for each item. The method for constructing this scale leaves out the use of judges and the task of sorting items into categories. Instead, an experimental group of subjects fills out such a form and the correlations among their responses are determined. Those items which correlate most highly with each other are retained for the final "scale," since they are assumed to tap the same attitude, while those which do not correlate are discarded.

Attitudes are measured by scales such as these, as well as by other techniques, to provide indications of the ways in which social behavior is being conceptually controlled. A knowledge of the attitudes of an individual provides a basis for predicting his behavior towards other people, or towards a social group. In addition, knowing an individual's current attitudes makes it possible to plan a change in them, should that be considered desirable. If we want to alter an individual's social behavior, we may attempt to teach him a new set of concepts, or at least to change old ones.

SUMMARY

In this chapter we have examined the various forms of social behavior as well as the effects of social factors on individual performance. The comparative study of culture shows the wide range of human behavior possible through social influences. Each *culture* exerts influence on the individual through its own pattern of selective reinforcement.

Each *culture* has its own *social structure* within which different people have certain roles assigned them. The interactions of people in these different roles is coordinated and controlled by some kind of *authority structure* and *reward system*. Different *statuses* within the system of social relationships are seen by members of society as differing in importance and prestige. In our culture, status differences are frequently tied to occupation.

Through the process of social stratification people of similar statuses organize into broader groups called *social classes*. Since individuals in our culture are motivated to change class membership from lower to higher status there is some *vertical mobility*.

Individuals are members of multiple *groups*, and these exert their own unique influences. The importance of group influences in industry was demonstrated by the Hawthorne studies. *Group norms* which develop are powerful influences in motivating individual behavior. These norms are enforced by a system of rewards and punishments within the group.

Groups may be described according to the kinds of personal interactions that go on in the group (e.g., intimacy, homogeneity), according to the social structure (e.g., control, stratification), or according to their goal-oriented behavior (cohesiveness, participation). The structure of groups also may be described by a *sociogram*. These often show the informal but functional interactions within the group, such as the cliques, isolates, and informal leadership patterns. Some ways of organizing groups are more effective than others in terms of the "*communication channels*" provided.

Morale is a group phenomena characterized by a goal common to all group members, a feeling of "togetherness" and "staying qualities." The type of leadership is an important factor contributing to morale and group functioning. *Leadership* is best defined as the act of influencing others rather than in terms of specific traits. The use of *group participation* has been shown to be an effective way of influencing group behavior. Group participation is especially effective in overcoming resistance to change by individuals in the group.

The behavior of individuals in supervisory positions can be described in terms of two broad behavior patterns, one concerned with establishing an attitude of warmth and respect with subordinates and the other with organizing and defining the tasks of group members in relation to group goals. The first of these patterns of behavior has been called *Consideration,* the second *Initiating Structure.* Supervisors may emphasize different degrees of each pattern. These patterns are related to such group behavior as accidents, absenteeism, turnover, and other criteria of effectiveness, but much depends on the type of situation. Effective supervisors tend to delegate authority, assume a role different from subordinates, and are not exclusively concerned with pushing production.

One of the most potent influences on the supervisor's behavior with his group is the leadership of his own supervisor toward him. Training in leadership for lower-level supervisors is not likely to be effective unless changes are made in the social environment and the reward system within which he operates.

Much social behavior is influenced by *attitudes,* which are learned predispositions to react in characteristic ways. In other words, they are concepts which control the social behavior of individuals. The measurement of attitudes in social groups makes possible the understanding and control of the individual's behavior toward other people and toward the group.

READING REFERENCES

Allport, G. W., *The nature of prejudice.* Reading, Mass.: Addison-Wesley, 1954. A single volume summary dealing with the psychological aspects of this problem.

Argyris, C., *Personality and organization.* New York: Harper, 1957. A review of human relations research in industry with special emphasis on the conflict between organization structures and individual needs.

Krech, D., and Crutchfield, R. S., *Theory and problems of social psychology.* New York: McGraw-Hill, 1948. A text in social psychology with chapters on social groups, leadership, and the formation and measurement of attitudes.

Maier, N. R. F., *Psychology in industry.* Boston: Houghton Mifflin, 1955. A basic text in industrial psychology, with chapters on morale, attitudes, and supervision.

Roethlisberger, F. J., and Dickson, W. J., *Management and the worker.* Cambridge, Mass.: Harvard University Press, 1946. A complete report of the pioneering studies at the Hawthorne plant of the Western Electric Company.

Shartle, C. L., *Leadership and executive performance.* Englewood Cliffs, N.J.: Prentice-Hall, 1956. This book deals with administrative and executive behavior in large organizations.

11

JOBS AND PERSONNEL SELECTION, I

By now you have learned about the major psychological concepts and principles which explain human behavior. Next you will see how these concepts are put to work in dealing with human beings in useful work situations. Beginning with this chapter and continuing to the end of the book, we shall be describing how psychological principles are used to select and train people for jobs, and to design new systems of operations in which human beings are to be employed. We begin with a consideration of human activities in jobs. You will read in this chapter how jobs develop in the first place, and how they are described and analyzed to provide information about needed human skills and abilities. Then we turn to the process of selection, by means of which people having the right combinations of abilities and interests are chosen for jobs. The theme of this chapter and the next is "matching the capabilities of human beings to the requirements of useful work."

We now turn to some methods of applying our knowledge about human abilities to human work. We have seen that each human being possesses a pattern of abilities which is unique to him as an individual. Furthermore, the specific skills he has learned are unique at any given time during his life. In contrast to this nearly infinite variety of patterns of abilities and skills, the work people do, while extremely varied, falls into a number of definable categories. The particular set of human activities required for some specific gainful employment of a single individual is called a *job*.

In this chapter we shall first consider how the total need for human activities in some productive enterprise gets divided into jobs which are assignable to individuals. We shall see the kinds of problems that are faced in the attempt to match patterns of work with patterns of human abilities and skills. This will bring us into contact with the process of *job analysis* in which jobs are described, and the skill and ability requirements determined. Then, we shall examine the process of *personnel selection,* which tries to fit men to jobs. Finally, we shall see how the effectiveness of this process can be determined by the *measurement of proficiency* of the individuals who occupy jobs.

OCCUPATIONS AND JOBS

There are many ways of categorizing the kinds of activities which make up human work. There are "unskilled labor," "blue-collar" jobs, "white-collar" jobs. There are "supervisory" jobs and "nonsupervisory" jobs. There are "line" jobs and "staff" jobs. There are "managerial" jobs, "artisan" jobs and "specialist" jobs. None of these categories has a clearcut relationship to required human abilities. Instead, they depend for their definitions on a complex of factors including the nature of organizations, amount of pay, length of training, and the degree of prestige they imply.

The most widely known method of classifying occupations is exhibited in the *Dictionary of Occupational Titles,* a volume prepared by the United States Employment Service. This method of classification is based upon logical distinctions in the kinds of work to be done, or what we shall call here the *types of operations.* Surveying all the kinds of work performed in the United States, the *Dictionary* identifies categories of operations in progressively more specific terms down to the level of the individual job. A summary of the major groups of occupations is contained in Table 11.1.

Within each of the occupational fields listed in specific lines of this table, are many *occupations,* and within each of these occupations is a number of individual *jobs.* For example, the occupational field of Printing contains the following *occupations:* compositors and typesetters, electrotypers, stereotypers, lithographers, photoengravers, pressmen and plate printers, bookbinding, rotogravure work, and wallpaper printing. Each of these occupations, in turn, may contain a number of individual job categories: for instance, the occupation of photoengraving comprises those of photoengraving etcher, cloth designs photoengraver, photoengraving finisher, photoengraving photographer, roto photographer, zinc platemaker, stripper, and platemaker foreman. Thus the word "occupation" simply refers to one level of specificity in identifying the operations required in a

TABLE 11.1
CLASSIFICATION OF OCCUPATIONAL FIELDS AND MAJOR SUB-FIELDS

- Professional and Managerial Occupations
  - Professional occupations
  - Semiprofessional occupations
  - Managerial and official occupations
- Clerical and Sales Occupations
  - Clerical and kindred occupations
  - Sales and kindred occupations
- Service Occupations
  - Domestic-service occupations
  - Protective-service occupations
  - Building-service workers and porters
- Agriculture, Fishery, Forestry, and Kindred Occupations
  - Agricultural, horticultural, and kindred occupations
  - Fishery
  - Forestry, hunting and trapping
- Skilled; Semi-Skilled; Unskilled Occupations
  - Occupations in Manufacturing and Related Activities
    - Production of food products
    - Manufacture of tobacco
    - Manufacture of textiles
    - Production of fabricated textile products
    - Production of lumber and lumber products
    - Production of paper and paper goods
    - Printing
    - Production of chemicals and chemical products
    - Production of petroleum and coal products
    - Production of rubber goods
    - Manufacture of leather and leather products
    - Production of stone, clay, and glass products
    - Metalworking
    - Manufacture of electrical equipment
    - Manufacture of transportation equipment
    - Manufacture of miscellaneous products
    - Miscellaneous manufacturing
  - Occupations in Non-Manufacturing Occupations
    - Extraction of minerals
    - Construction
    - Transportation
    - Communication and utility
    - Trade and service
    - Public-service
    - Miscellaneous
  - Foremen (skilled only)
  - Apprentices (semi-skilled only)

(From U. S. Dept. of Labor, *Dictionary of Occupational Titles,* Washington, D. C.: U. S. Government Printing Office, 1939.)

given occupational field such as printing. If we ask a man what is his *occupation,* he may reply correctly, by custom, that he is in photoengraving. However, if we are interested in greater specificity than this, we may ask what is his *job.* To this he may reply by naming the job category of photoengraving etcher (or some other specific job within this occupational category).

The important terms used in identifying and categorizing human work, as we use them in this book, are these:

OCCUPATION. This is a group of jobs all connected with some unit of operations which produces either a single product or a set of similar products. (For example, the group of jobs in *photoengraving* are all connected with the operation of producing photoengraved copper or zinc plates used for printing.)

JOB CATEGORY. This is a typical set of human activities, forming a part of a larger set of operations, which is performed in a *class* of individual jobs. For example, the set of human activities which is typically carried out by individuals in jobs called *photoengraving etcher* is what is meant by a job category. The *Dictionary of Occupational Titles,* Volume 1, contains brief descriptive summaries of the activities required in over 22,000 job categories.

JOB. It is possible to arrive at a level of specificity for the identification of human work which goes beyond the job category. And in order that an analysis of human abilities required in such categories can be made, it is in fact necessary to go further. Each individual set of human activities to be performed by one person in a particular plant (or other organization) is called a *job.* The job has a unique description which may correspond more or less closely with that of a job category. In other words, a job category is an abstraction from many individual jobs all over the United States, and is therefore a kind of standard against which jobs may be compared. When we are dealing with the unique operations of a particular plant it is easy to see that these may conform more or less to such a standard. Or, when an entirely new product is being made, and an entirely new set of operations is being established, the required jobs may or may not be like "standard" job categories, as defined by the *Dictionary.* The job, therefore, is simply a particular instance of a job category.

TASK. The basic descriptive statement in a job description is called a task. Tasks are statements of individual human activities which, taken all together, constitute the job. We shall have occasion to examine these later in more detail, since they are the key to the derivation of human abilities required by jobs. Figure 11.1 summarizes these four basic categories of occupational description, and indicates the increasing specificity of each category as we have described them here.

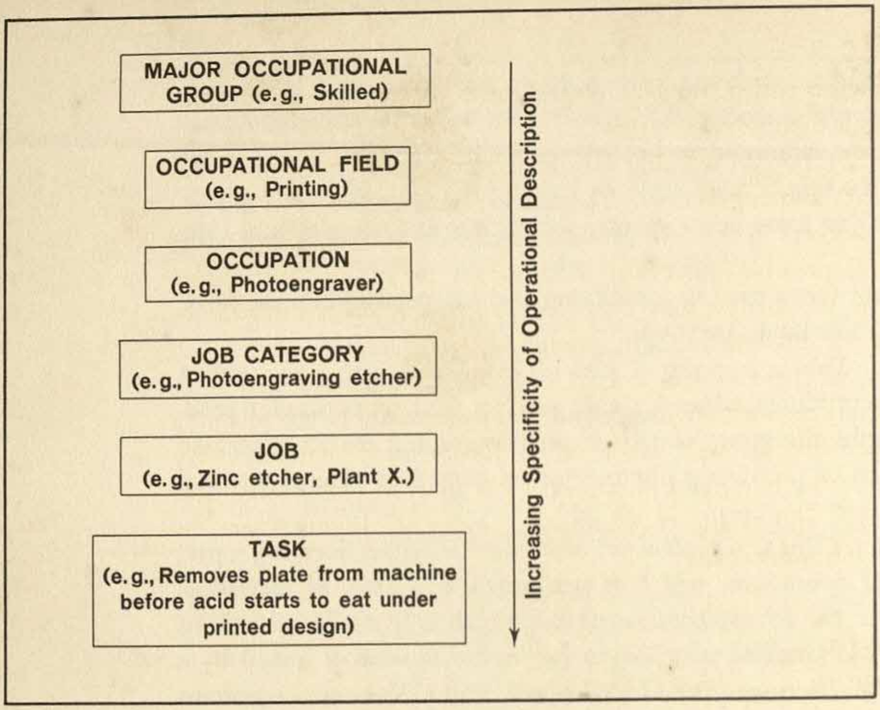

MAJOR OCCUPATIONAL GROUP (e.g., Skilled)
OCCUPATIONAL FIELD (e.g., Printing)
OCCUPATION (e.g., Photoengraver)
JOB CATEGORY (e.g., Photoengraving etcher)
JOB (e.g., Zinc etcher, Plant X.)
TASK (e.g., Removes plate from machine before acid starts to eat under printed design)
Increasing Specificity of Operational Description

FIGURE 11.1. *The major categories of occupational description, arranged in order of increasing specificity. An example of the appropriate title or description is given for each level. For example, the Task here described is a part of the Job: Zinc Etcher, Plant X; which in turn is a single example of the Job Category: Photoengraving Etcher; and so on.*

The systematic process and procedure of actually obtaining such occupational information and organizing it meaningfully is known as *job analysis*. The major products of a job analysis are two. First, there is a *job description*, which details the tasks, materials, and tools for a given job in some organized form. Second, derived from the job description are the *skill and ability requirements* needed to carry out the tasks of the job.

JOB ANALYSIS

Sources of Information

The person conducting job analysis obtains information about the job in various ways. The available sources differ somewhat depending on whether existing jobs with incumbents must be described or whether the operation is new and one must forecast what the jobs will be like. The need to undertake analysis of jobs on the latter basis is growing in frequency with the rapidly changing technical developments and new products of our modern society. For example, jobs connected with exploration of space or with the use of nuclear power must be forecast in advance, since the operations themselves are new.

When there are people working in jobs it is, of course, possible to interview incumbents and supervisors. The analyst may also observe directly the behavior of workers in the job. Training manuals, textbooks, operating procedures are all possible sources of information regarding the tasks of existing jobs. The job analyst may even perform in the job himself to obtain information for his analysis. In predicting from scratch what a job will be like, many of these sources are not available. The analyst may have to rely on consultations with engineers and plant personnel in the planning stages of the operation, as well as on other documentary materials. We shall illustrate here the two main phases of a job analysis (job description, and analysis of skill and ability requirements) under conditions where the forecast of a new job is necessary.

Job Description

DESCRIBING OPERATIONS. When a new industrial process is to be set up, it is conceived in terms of a sequence of operations. For example, suppose a new factory is planned to produce a finished product called a gimcrack, made of a new metal alloy. It would be necessary to conceive the entire set of production operations in some such terms as these:

1. Receiving
2. Metal Processing
3. Rough Casting
4. Machining
5. Parts Supply
6. Gimcrack Assembly
7. Product Inspection
8. Packaging
9. Shipping

These *operations* have a basic importance for job description in that they identify the environment within which the job will take place. For example, the receiving and storage operation probably takes place in a different part of the factory from that which houses rough casting. A different set of supervisors will also be involved. The operation of gimcrack assembly may have to be done in an air-conditioned, dust-free environment, whereas metal processing may produce much heat in the part of the factory which houses it. The sequence of these operations also helps to define some basic facts about the job. The operation of machining, for example, is done after rough casting, which tells something about the type of materials a worker in machining will be concerned with.

But an important thing to note is that these operations *do not* define the jobs in the sense of telling us what the individual must do. If a worker were to tell us he works in "gimcrack assembly" we should know almost nothing about the human activities required by his job. It would be a mistake to assume that all jobs in "gimcrack assembly" are alike or even that they are more nearly alike than are jobs in two different operations. The verbs used to describe operations, like "receiving," "processing," "machining," "assembly" identify the goals of operations only. They tell us little about human behavior.

DESCRIBING TASKS. As we have said, the basic element of a job description is called a *task*. The task is the smallest part of a total operation which would be assigned to a man to complete as a step in that operation. The entire job, of course, is made up of many tasks. A task statement identifies the stimulus situation to which the individual responds, the performance exhibited, and the skills (specific habits, motor skills, models, sequences, concepts) which underlie the performance. A typical task statement may be written as follows:

Activity	*Performed On:*	*Tools Used:*	*Specific Skills*
Inspects gimcrack shaft to measure 1.25 inches ± 0.05 OD	Assembled gimcrack	Micrometer	Rule for micrometer reading Rule for subtraction Skill in manipulating micrometer Visual alignment Pressure discrimination

With the statement of a task, we come to a level of detail and specificity of description which is both meaningful and dependable. The description of the "Activity," the item the activity is "Performed On," and the "Tools Used," permit the reader of this description to imagine the task being performed. This is an important characteristic, since a job description should be designed to be read and understood by other people.

DESCRIBING SKILLS. Some of the most essential uses of job descriptions in connection with fitting men to jobs are fulfilled by the inferences made about specific skills. One can only prepare descriptions in these terms by using psychological concepts about human functions, of the sort described in previous chapters of this book. The columns "Activity," "Performed On," and "Tools Used" require information only about equipment to be used and its environment. In contrast, describing "Specific Skills" takes knowledge of human behavior functions. In deriving skill descriptions the psychologist infers from the task activities the specific discriminations, habits, models or scales, motor skills, verbal sequences, concepts, or problem-solving needed. To be able to make these inferences, he must have an understanding of the task of sufficient scope and dependability that he can identify the stimuli and responses involved in the task behaviors.

How can one arrive at the specific skills to be identified in a job description? This may be done by running down a list of human functions and deciding whether each is involved in the task. Table 11.2 shows the results of such an exercise for the task under discussion. In drawing the conclusions required, the job analyst must perform a process similar to that indicated in Table 11.2 for each task of the job. He may do this in his head, of course, rather than taking the time to actually construct such a table.

TABLE 11.2
DERIVATION OF SPECIFIC SKILLS REQUIRED IN THE TASK: INSPECT GIMCRACK SHAFT

Task Behavior		Specific Skills
Action	*Indicator*	
1. Recall of 10-step sequence	None	Sequence: 10 steps
2. Turn set-screw to fully expanded position	Feel of screw against stop	Discrimination: pressure
3. Insert gimcrack shaft in slot to end of slot	Feel of contact with end of slot	Discrimination: pressure
4. Pull out gimcrack shaft until mark on shaft is aligned with edge of slot (0.05 in.)	Visual alignment of mark with edge of slot	Discrimination: visual
5. Hold shaft in position	Visual alignment of mark with edge of slot	Discrimination: visual
6. Tighten set-screw on shaft with wrench	Feels "tight"	Motor skill using wrench
7. Turn on counter switch	Visual check of "on" position	Identification: switch position
8. Read counter in five digits	Five-digit direct reading counter	Identification: number scale
9. Subtract to find differences in reading from 1.2500 in.	None	Concept: Subtraction rule
10. Classify as "accept" or "reject"	Difference less than or greater than 0.0500 in.	Identification: number scale
11. Place in "accept" or "reject" bin	Visual check of bin position	Identification: bin position

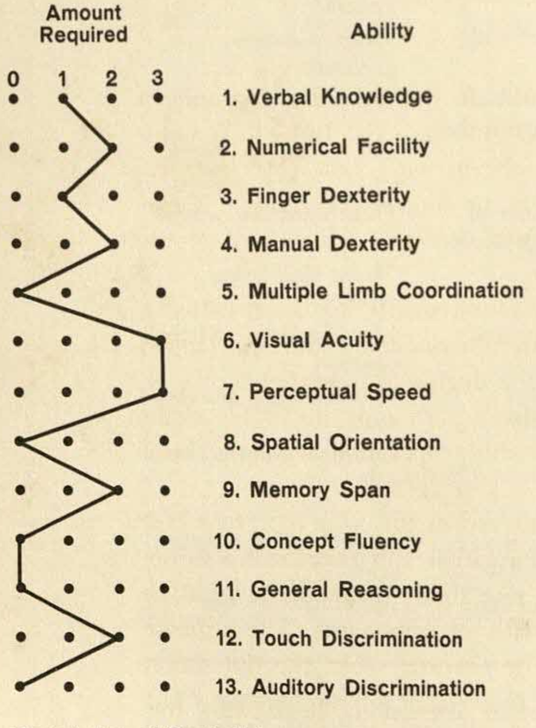
The important things to note about the process, however, are these:

1. The task is thought of in terms which describe *responses* and *stimuli*, rather than operations. These are given in the columns labeled "Action" and "Indicator" respectively.

2. Description of these task behaviors enables the psychologist to understand and interpret jobs in terms of the human functions described in this book. These provide a basis for drawing conclusions about what specific skills need to be present in the individuals to be selected and trained for the job.

DERIVING ABILITY REQUIREMENTS. In Chapter 5 we saw that individual differences in general abilities underlie proficiency in many specific kinds of skills on particular tasks. At this stage of the job analysis, with the information at hand, it is possible to make inferences about the abilities desir-

FIGURE 11.2. *Job profile showing estimates of relative importance of different abilities for "gimcrack assembly" job.*



Description of Scale Values:

0 - The ability is not required for satisfactory performance.

1 - An average amount is required in some task elements.

2 - An above-average amount is required in numerous task elements or in a major task.

3 - A very high amount of the ability is required in some task elements.

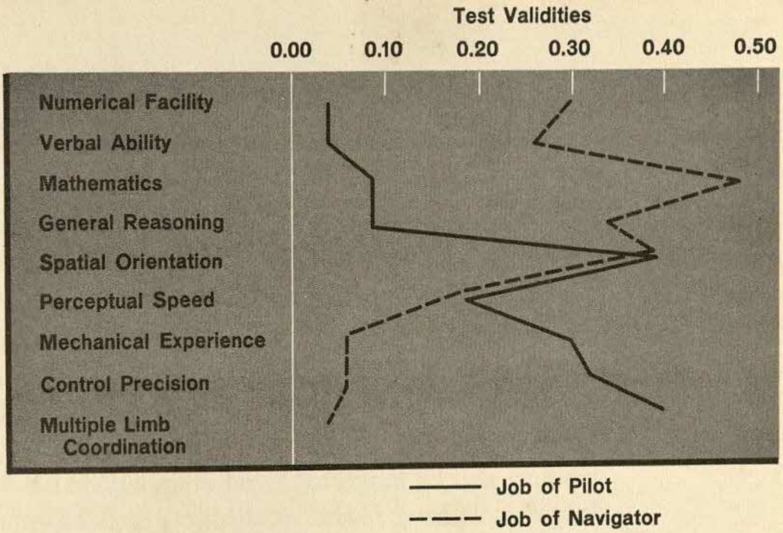


FIGURE 11.3. *Correlations between scores on tests in several ability areas with proficiency of pilots and navigators. (Data from Guilford, J. P., and Lacey, J. T. (Eds.),* Printed Classification Tests. *Army Air Forces Aviation Psychology Program, Research Report No. 5, Washington, D. C.: U. S. Govt. Printing Office, 1947; and from Melton, F. W. (Ed.),* Apparatus Tests. *Army Air Forces Aviation Psychology Program, Research Report No. 4, Washington, D. C.: U. S. Govt. Printing Office, 1947)*

able for the particular combination of tasks in this job. For example, it may be found that a number of tasks require motor skills. But which motor abilities are likely to facilitate performance in each task (for instance, *finger dexterity, multiple limb coordination,* or *control precision*)? A correct answer to this question will make possible efficient selection of people for the job.

One way of representing the ability requirements has been called a *job profile.* This includes a number of carefully defined abilities, arranged on a scale on which the analyst can rate the degree of importance of each ability. Figure 11.2 gives an example of what a portion of this profile might look like for a job in the gimcrack assembly operation we have been describing.

Note that the ability requirements inferred in this way represent best estimates or "hypotheses," subject to confirmation and revision by subsequent experience with job incumbents. These ability estimates suggest the kinds of tests which should be tried out with job applicants. The ultimate usefulness of these ability estimates can be checked when the test scores made by applicants are correlated with their later job proficiency. The United States Employment Service, for example, has continuously refined its estimates based on correlations of this sort. Figure 11.3 shows an instance of a set of ability requirements which are based on correlations of test results with job performance. Such data are not available, of course, when one is setting up a new job; in such a case, the psychologist has to rely on his knowledge about human abilities and skills.

SELECTION OF PERSONNEL

Once the nature of a job has been determined, a next step is to establish procedures for selecting personnel who best meet the job requirements. The problem is to identify those individuals with the proper combination of abilities, skills, interests, and motives who will learn the new job skills most quickly and reach a high level of proficiency on the job. Of course, we may also be interested in selecting individuals who will stay on the job longer, will have fewer accidents, or will be promotable to higher-level jobs. In any case, the problem becomes one of predicting ahead of time which individuals will eventually succeed in a given job.

It can readily be seen that the approach to this problem may be derived from our discussion of individual differences in Chapter 5. Behavioral differences between people at the time of employment are related to differences between them observed in later job proficiency. From the description of the job, estimates may be made of what the relevant characteristics are for job performance. Through such typical employment methods as psychological tests, application blanks, and employment interviews, these characteristics can be assessed in job applicants. In the following sections we will examine these methods and the conditions under which they are likely to be most effective. First, however, let us examine some practical consequences of individual differences on the job.

Individual Differences on the Job

Differences among Job Applicants. In Chapter 5 we saw many examples of the range and distribution of individual differences within large populations on a variety of human abilities. But what about the distribution of abilities among applicants for a particular job? There are usually great differences, even among applicants with very similar backgrounds. Figure 11.4, for example, shows a distribution of scores made by applicants for machine shop apprenticeships on a shop information test. All applicants had either a high school vocational course or experience as machinists' helpers. Thus, in spite of similar opportunities to learn, wide differences existed in actual qualifications.

Differences in Required Abilities among Job Incumbents. Figure 11.5 shows a distribution of scores on a measure of *finger dexterity* obtained

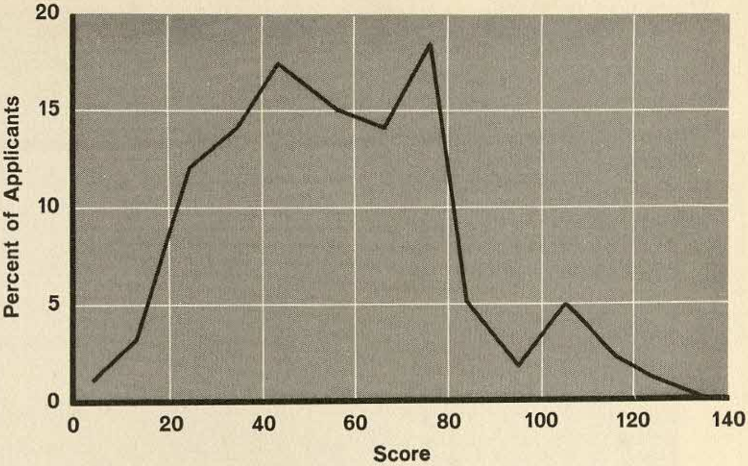
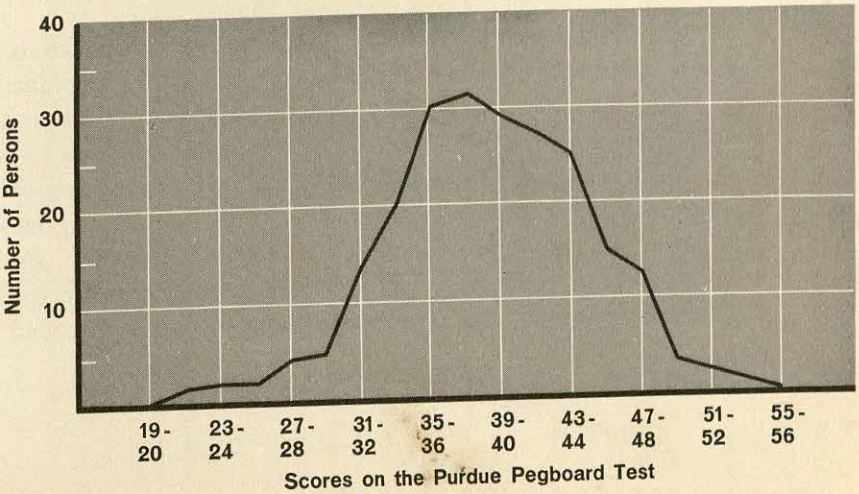


FIGURE 11.4. *Distribution of scores of machine-shop applicants on a shop information test. (After Tiffin, J.,* Industrial psychology. *New York: Prentice-Hall, 1944)*

from 227 aircraft electricians already on the job. It is clear that even after selection, the distribution of scores on this measure approximated the distribution obtained in a random sample of the population. It turned out that persons who scored high on this measure were also more proficient in this job. In other words, the selection procedure in use, which did not include this test, had overlooked a relevant ability. It is possible that after a period of time many individuals at the low end of the distribution of finger dexterity scores might fail in the job, or be transferred.

DIFFERENCES IN JOB PROFICIENCY. Differences in job proficiency are more obvious. As we indicated in earlier chapters such performance is a joint function of motivation and ability. However, the magnitude of these

FIGURE 11.5. *Distribution of finger-dexterity scores of aircraft electricians already on the job. (Data from Fleishman, E. A., Predicting success in certain aircraft maintenance specialties by means of manipulative tests. Lackland Air Force Base, Texas; Air Force Personnel and Training Research Center, Research Report 55-23, September, 1955)*



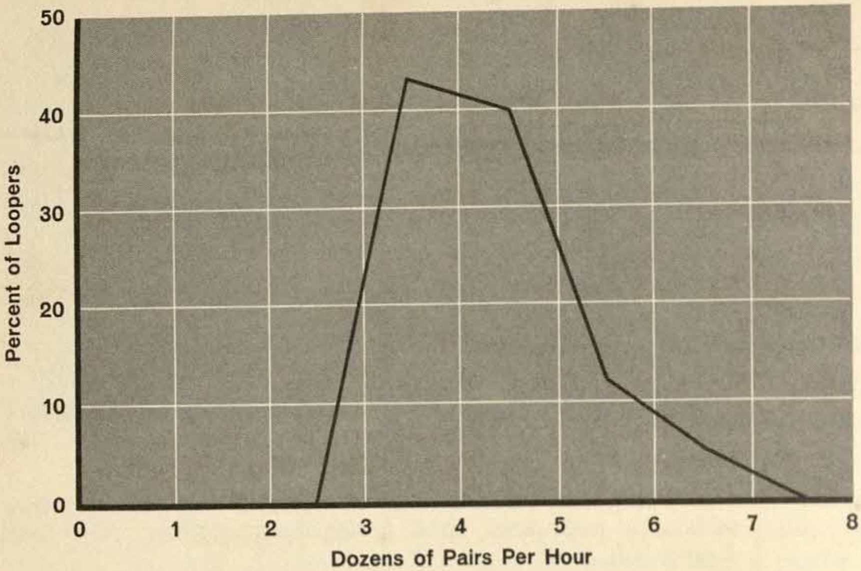


FIGURE 11.6. *Distribution of output for hoisery loopers, on the job more than one year. (After Tiffin, J.* Industrial psychology, *New York, Prentice-Hall, 1944)*

differences is not always appreciated. The range of performance is sometimes expressed as a ratio of the production of the least productive employee to that of the most productive. These ratios vary, but ratios of 1 to 2 are common, and for some jobs the ratio is 1 to 5. Training and equivalent experience do not eliminate such differences. Figure 11.6 shows the distribution of output for 99 "hosiery loopers" in a textile mill, all of whom had been on the job one year or more. It can be seen that the best operator was producing over 3 times as much per hour as the least productive operator.

It is important to note that differences among employees in performance are typically consistent over time. In other words, the employee who produces highly at one time tends to remain at a high level, and the low-producing employee tends to remain at a lower level. In the case of the 99 hosiery loopers in Figure 11.6 the correlation of production for one week with production the next week was .96.

Similar stability of performance applies to other kinds of job behavior. In one study, records of absenteeism, accidents, grievances, and turnover were taken from different foremen's work groups over an 11-month period. The records for odd weeks were correlated with those for even weeks during this period. Table 11.3 shows the high correlations obtained. In other words, work groups high in absenteeism, accidents, grievances, and turnover one week were likely to be high other weeks. From our previous chapter we may infer that this was in large measure related to the foreman's behavior. In fact, it was found that foremen tended to be consistent

TABLE 11.3

CONSISTENCY OF ON-THE-JOB BEHAVIOR FOR 112 WORK GROUPS OVER AN 11-MONTH PERIOD

Absenteeism	.85
Accidents	.72
Grievances	.73
Turnover	.59

(From Fleishman, E. A., Harris, E. F., and Burtt, H. E. *Leadership and supervision in industry*. Columbus, Ohio, Bureau of Educational Research, Ohio State University, 1955.) These figures are correlations between the records totaled for odd-numbered weeks and those totaled for even-numbered weeks.

in their "Consideration" and "Structure" behavior over this 11-month period. Thus there are indications that individual differences in supervisory behavior, as well as employees' behavior, tend to persist over time on the job.

Personnel Selection Procedures

How are applicants matched to the requirements of jobs? At one time, a typical procedure was for the foreman with a vacancy in his department to talk to an applicant for a few minutes and then to hire or reject him.

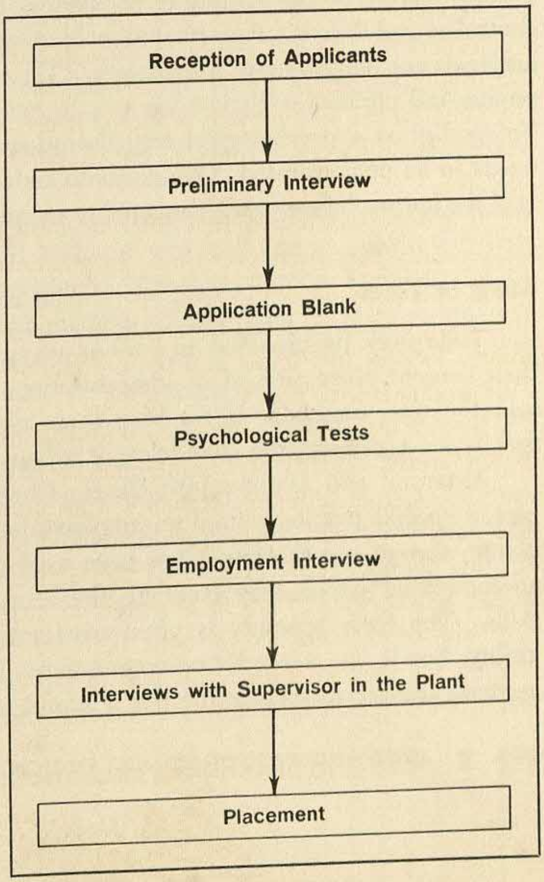


FIGURE 11.7. *Steps in the personnel-selection procedure of a large company.*

But the appraisal of individual characteristics which are highly predictive of job success cannot be done this way. Instead, more precise assessments must be made of the various kinds of individual differences which may be important to job performance. The three primary techniques used for making such assessments are *psychological tests, application blanks,* and *interviews.* We shall consider in the following sections some of the characteristics of these methods, and the ways they are used in selecting personnel.

PSYCHOLOGICAL TESTS

Psychological tests are used widely for selection purposes in industry, in universities, and in government agencies. A psychological test is essentially *a standardized measure of a sample of an individual's behavior.* Any one test is designed to sample only a limited aspect of behavior. By analogy, the chemist samples only a few cubic centimeters of liquid and infers the characteristics of the entire compound from this sample; the quality control engineer does not test every finished product, but only a sample of them. Similarly, the psychologist may diagnose "vocabulary" from a measure based on a small number of words, or he may infer the level of a person's *multiple limb coordination* by having him make certain movements. The most important feature of this sample of behavior is that it is taken under certain controlled conditions. Performance on just any sample of words, for example, is not diagnostic of "vocabulary." The so-called "tests" seen in newspapers and popular magazines are usually not tests at all by our definition. To qualify as a psychological test, the adequacy of the behavior sample needs to be demonstrated. One needs to know how representative any test is of the human behavior it is designed to sample.

Kinds of Tests

Tests may be classified in various ways according to their purpose, their content, their method of administration, or the medium used to present the test materials. If we keep these classifications in mind we can specify, or ask about, the most relevant information for each particular test.

APTITUDE AND ACHIEVEMENT TESTS. Chapter 5 provided many examples of specific test items used to sample various human abilities. The term *ability,* throughout this book, has been used to refer to a general trait of an individual which may facilitate the learning of a variety of specific skills. The term *aptitude* is often used interchangeably with the term ability, but it has a *predictive* connotation. Thus, when we speak of an aptitude test we mean that the test is useful for predictive purposes about a person's future success in some activity. Aptitude tests may be designed to measure single ability traits which are of varying importance in a number of different occupations. Thus, there are tests of *spatial orientation* and *verbal fluency*. Aptitude tests may also be designed to predict success in a *particular* occupation or job, as would be true of a test of "clerical aptitude." Such a test would actually measure a number of different abilities found to be important in clerical jobs. Both kinds of aptitude test are designed to provide measures of abilities *predictive* of performance.

Achievement tests (or proficiency tests), on the other hand, are designed to measure degree of mastery *already achieved*. Such tests attempt to evaluate how well the individual can perform now or how much he has learned in training. Thus, an employer may want to know an individual's job knowledge (e.g., about use of tools or terminology) or his job skill. *Trade tests* are examples of achievement tests for a specific job. Later we shall see how proficiency tests are used in assessing job knowledge.

MODE OF PRESENTING TESTS. Most tests are of the paper and pencil variety, in which material is presented on a printed page and the response is made by marking with a pencil on a paper. The administrative advantages of such a medium are obvious, in that many individuals can be tested at once, fewer examiners are needed, and scoring of the tests is relatively straightforward. Apparatus tests often present problems of maintenance and calibration. However, it may not be possible to assess the desired behavior by means of purely printed media. Tests of manual dexterity or multiple limb coordination (see Chapter 5) are examples of aptitude tests requiring apparatus, varying from a simple pegboard to a mechanical-electronic device. Tests for children and for illiterates frequently employ blocks and other objects which are manipulated.

Auditory and motion picture media have also been used in testing. For example, tests of "musical aptitude" are auditory, as are certain tests designed to select radio-telegraphers. The test material is presented by means of a phonograph or tape recorder. Figure 11.8 gives an example of two frames from a test using motion picture presentation. This test was designed to measure how well individuals could estimate the relative velocity of moving objects. It is evident that this function could not have been measured by a purely printed test. However, in both these kinds of tests, the responses are made by pencil on paper.

GROUP VERSUS INDIVIDUAL TESTS. Some tests can be administered to examinees in a group, while others can be administered to only one person at a time. The *individual* test is naturally more expensive to use in a testing program. Tests for very young children or tests requiring oral responses must be individual tests. Such tests are also used when an individual's performance must be timed accurately. Devices used to test motor abilities

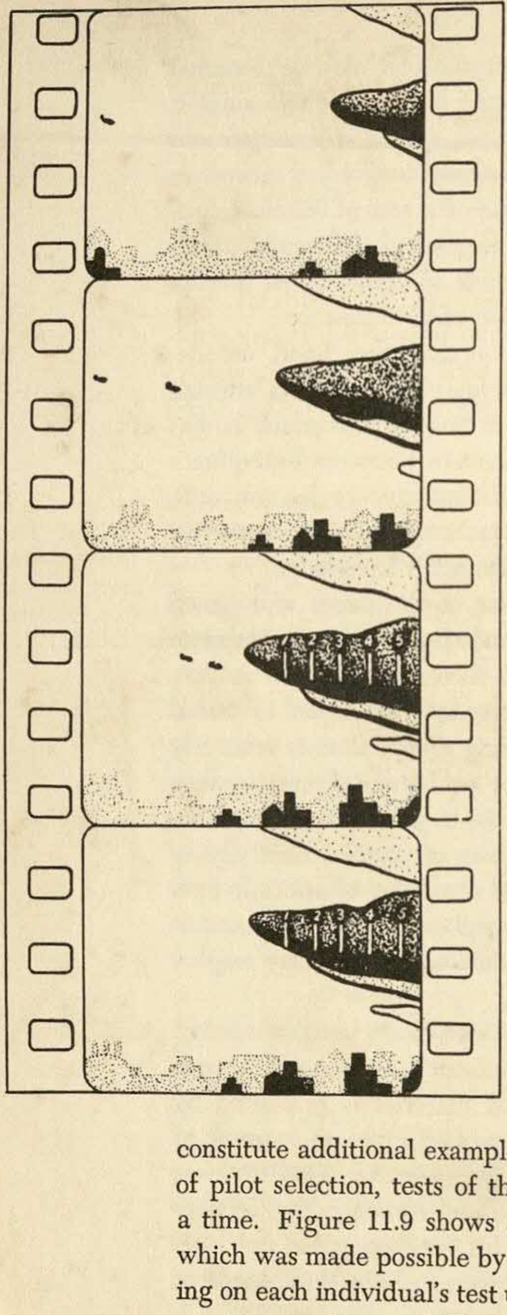


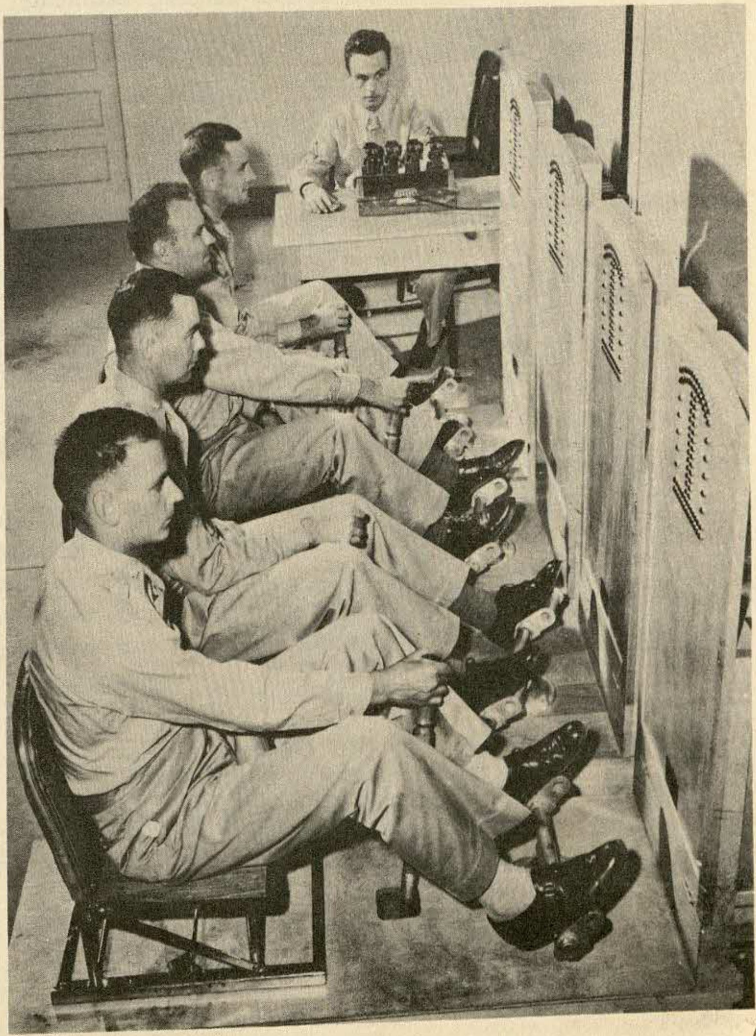
FIGURE 11.8. *Stages in a sample item of the Estimation of Relative Velocities Test. The examinee is required to mark on his answer sheet the point (1, 2, 3, 4, or 5) at which the two airplanes met. (From Gibson, J. J. (Ed.),* Motion picture testing and research. *Army Air Forces Aviation Psychology Program,* Research *Report* No. 7, *Washington, D. C.: U. S. Govt. Printing Office, 1947)*

constitute additional examples of individual tests. In the Air Force program of pilot selection, tests of this sort were frequently given to four people at a time. Figure 11.9 shows an example of one of these test arrangements, which was made possible by wiring into a central console the scores registering on each individual's test unit.

SPEEDED VERSUS NON-SPEEDED TESTS. Tests differ in the emphasis placed on speed. In many functions, such as vocabulary, there is little interest in speed. Such tests are called *power tests* and have no time limits. For other functions, such as *perceptual speed* or *finger dexterity,* speed becomes an important factor in the measured behavior. *Speeded tests* may be administered by allowing all examinees a specific length of time to finish, in which case the score is represented by the number of items correctly completed. Alternatively, a speeded test may require the examinee to finish a task as rapidly as possible, and his score may then be expressed as time taken to complete the test. For example, a finger dexterity test may be scored as number of seconds taken to complete a series of small screw-washer-nut assemblies.

WHAT THE TESTS MEASURE. Most frequently, tests are classified in terms of the ability, skills, or knowledge they measure. There are vocabulary tests, motor ability tests, intelligence tests, and tests which measure all the kinds of abilities described in Chapter 5, as well as tests of personality and interest.

FIGURE 11.9. *Example of a psychomotor testing session in the Air Force pilot-selection program. The test is the Complex Coordination Test. The examiner has before him four automatic counters, one for each testing device, which record the number of correct responses completed.* (From Melton, A. W. (Ed.), Apparatus tests. *Army Air Forces Aviation Psychology Program, Research Report No. 4, Washington, D. C.: U. S. Govt. Printing Office, 1947*)



Personality and Interest Measures. In general, personality testing lags behind ability testing in its positive accomplishments. In the employment situation particularly, such tests have not been as useful as one might expect. The reason for this is not that personality factors are unimportant, for certainly they are of great importance to the performance of useful work. But many difficulties have been encountered in developing adequate methods of measuring personality factors for these purposes.

The designation "personality test" refers to measures of such individual characteristics as persistent motivations, emotional adjustment, interests, and social relationships. There are several approaches to personality measurement. The most frequently used is the printed questionnaire or *self-report inventory*. There is a great variety of traits which these questionnaires attempt to measure. One such inventory contains 300 items, 30 for each of the ten traits, defined as follows:[1]

G. General Activity—hurrying, liking for speed, liveliness, vitality, production efficiency vs. slow and deliberate, easily fatigued, inefficient.

R. Restraint—serious-minded, deliberate, persistent vs. carefree, impulsive, excitement loving.

A. Ascendance—self-defense, leadership, speaking in public, bluffing vs. submissiveness, hesitation, avoiding conspicuousness.

S. Sociability—having many friends, seeking social contacts and limelight vs. few friends and shyness.

E. Emotional stability—evenness of moods, optimistic, composure vs. fluctuation of moods, pessimism, daydreaming, excitability, feelings of guilt, worry, loneliness, and ill health.

O. Objectivity—thick-skinned vs. hypersensitive, self-centered, suspicious, having ideas of reference, getting into trouble.

F. Friendliness—toleration of hostile action, acceptance of domination, respect for others vs. belligerence, hostility, resentment, desire to dominate and contempt for others.

T. Thoughtfulness—reflective, observing of self and others, mental poise vs. interest in overt activity and mental disconcertedness.

P. Personal relations—tolerance of people, faith in social institution vs. fault-finding, critical of institutions, suspicious, self-pitying.

M. Masculinity—interest in masculine activities and other emotional responses characteristic of men vs. interest in feminine activities and other emotional responses typical of women.

Examples of the items in this kind of inventory are the following:

You are often in low spirits	Yes	?	No
You start work on a new project with a great deal of enthusiasm	Yes	?	No

It is easy to see why such measures have limitations in employment situations. The main reason is they are easily "faked" by applicants who want to be hired. Although techniques have been developed for minimizing, detecting, and even scoring "faking," it is still a problem which has not been adequately solved.

A second approach to the study of personality is the *projective test.* The examinee is given a relatively "unstructured" stimulus such as those in the Rorschach Inkblot Test. Since the stimulus has no meaning, it is inferred that the examinee's response reflects his characteristic aspirations, fears, aggressions, and motives. There are various types of projective tests, some involving pictures, others simple verbal material. In one such test, the examinee is asked to complete the thought in sentences beginning "I feel . . . . . . ", "Women . . . . . . ", My father . . . . . . ". A great deal of interpretation is of course required in deriving motives from answers to these questions. Although projective tests are extensively used in counseling for personal adjustment, their value for the selection of personnel has yet to be demonstrated.

The strength and direction of an individual's *interests* are important aspects of personality. The persistence of an individual's interests over more than twenty years and their relationship to occupational choice has been demonstrated.[2] Measures of interests, which sometimes take the form of *questionnaires,* have thus been especially useful in vocational and educational counseling. Besides identifying kinds of interest, questionnaires usually make possible a measurement of *strength* of interests along a scale. The best-known forms of interest questionnaires are designed to determine whether the examinee's interest pattern agrees with the interest pattern of men already in a great variety of professions and occupations (for example, physician, carpenter, artist).[3] The questions elicit information about preferences for, and degrees of liking for, a great variety of human activities, including both working activities and spare-time occupations.

Interest questionnaires have many of the disadvantages of the personality inventory when administered to job applicants, particularly with reference to "faking" possibilities. However, when there are a number of possible job assignments for a given group of applicants, interest inventories can be useful in adding predictive power when combined with ability measures. The principles for evaluating the usefulness of personality and interest measures are much the same as those we shall now describe for other kinds of tests.

Characteristics of Useful Tests

Now that we have looked briefly at the different forms of tests, let us examine some of the basic concepts of testing. How can the usefulness of a test be evaluated? How can a test score be interpreted? Before a test is actually used in selecting workers a number of conditions have to be met. There is a period of "testing the tests" to determine their applicability in particular situations.

STANDARDIZATION. The concept of standardization refers to the establishment of uniform conditions under which the test is administered. The intention here is to make sure that the particular ability of the examinee is the sole variable being measured, to the exclusion of other factors. A great deal of care is taken to insure proper standardization of testing conditions. Thus, the examiner's manual for a particular test specifies the uniform directions to be read to everyone, the exact demonstration, the practice examples to be used, and so on. The examiner tries to keep motivation high and to minimize fatigue and distractions. If such conditions are high for one group of job applicants and not for another, the test scores may reflect motivational differences in addition to the ability differences which it is desired to measure.

NORMS. A test score has no meaning by itself. The fact that Joe answered 35 words correctly on a vocabulary test, or that he was able to place 40 pegs in a pegboard in two minutes gives very little information about Joe's verbal ability or finger dexterity. These scores are known as *raw scores*. In order to interpret Joe's raw score it is necessary to compare it with a distribution of scores made by a large number of other individuals who have taken the same test. Such distributions are called *norms*. There may be several sets of norms for a particular test, applicable to different groups of examinees. Thus, getting 75 percent of the vocabulary items correct may turn out to be excellent when compared to norms based on high school students, but only average when compared to norms based on college graduates. If one is using a test to select engine mechanics, it is best to compare an applicant's score with norms obtained from previous applicants for this job as well as with norms of actual mechanics.

In Chapter 5 on Human Abilities we described the *mental age norm*, in which an individual's score on an intelligence test is compared to the average score obtained by people of different ages. This, of course, is applicable mainly to children. For adults the *percentile* norm is most frequently used. A large number of people (at least several hundred) are tested, the scores ranked, and the percentage of people falling below each score is determined. Let us suppose that an individual who gets a raw score of 35 on a test turns out to be at the 65th percentile. This tells us immediately that the person scored better than 65 percent of the individuals in the group for which test norms were determined. A score at the 50th percentile is, by definition, the median of the distribution. The scores made by future applicants for a job may subsequently be evaluated by comparing them with the percentiles of the norm group.

Another type of norm is the *standard score*, which we discussed in Chapter 5. It will be recalled that each individual's score can be expressed as a discrepancy from the average score of the entire group. When we divide this deviation by the standard deviation (*S.D.*) of the group we have a standard score, or a score expressed in *S.D.* units. Typically, a test manual will include these standard-score equivalents as well as percentile equivalents for each raw score. Table 11.4 compares a distribution of raw scores made by a norm group on a test with the percentile and standard-score equivalents.

TABLE 11.4
CONVERSION OF RAW SCORES TO PERCENTILES AND STANDARD SCORES FOR A TEST OF HAND-GRIP STRENGTH. NORM GROUP—MALE COLLEGE FRESHMEN

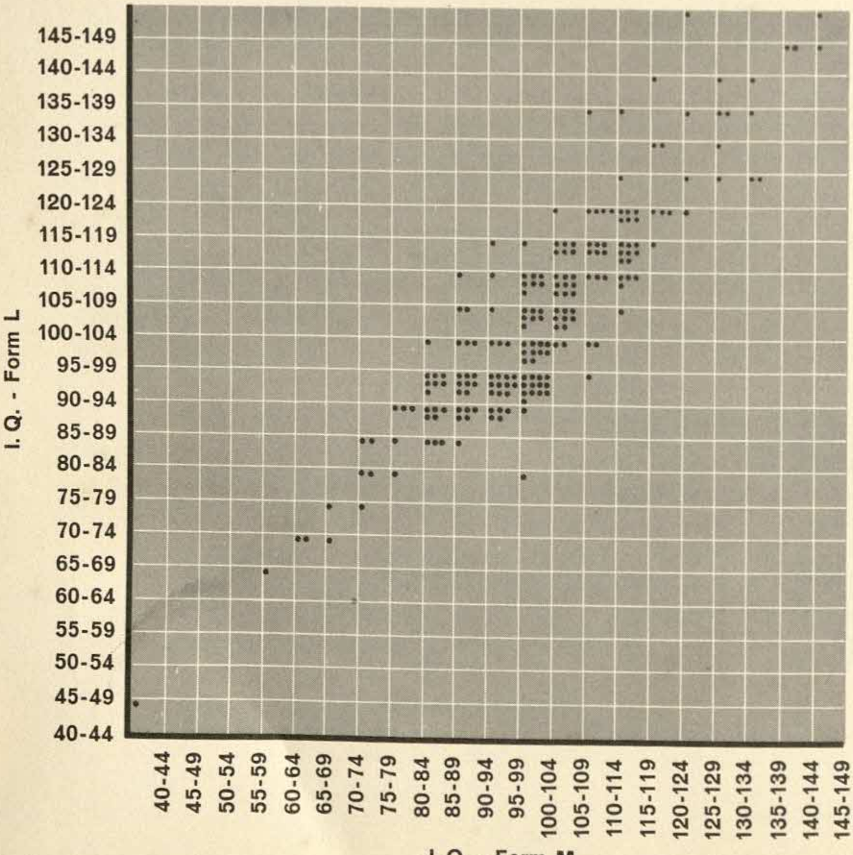
RAW SCORE *(in pounds of pressure)*	PERCENTILES	STANDARD SCORES *Z-scores*	STANDARD SCORES *T-scores*
180	99.9	3.0	80
171	99.4	2.5	75
163	97.7	2.0	70
154	93.3	1.5	65
145	84.1	1.0	60
137	69.2	0.5	55
128	50.0	0.0	50
120	30.9	–0.5	45
111	15.9	–1.0	40
103	6.7	–1.5	35
94	2.3	–2.0	30
86	0.6	–2.5	25
77	0.1	–3.0	20

(Data from Rusack, H. N., A study of corrective strengths of college freshmen to ascertain their norms and improvements during the year. M.A. thesis, Springfield College, 1932.) *T*-scores are frequently used standard scores. These are computed by multiplying each person's Z-score by 10 and adding 50. This eliminates the use of negative signs and places the mean of the group at 50 with a standard deviation of 10.

From this discussion, it is evident that a psychological test usually has no arbitrary pass-fail score. Students of psychology are sometimes amused to learn that a public official may express himself as being deeply shocked that half of the children in this country score below average on an intelligence test!

RELIABILITY. One of the most important characteristics of a test is called *reliability*. This refers to the *degree to which the test measures something consistently*. If a test yielded an I.Q. of 135 for an individual one day and 85 the next, we would term the test unreliable. Before psychological tests are used they are first evaluated for reliability. This is often done by the *test-retest* method, which involves giving the same test to the same individuals at two different times. The question which expresses reliability is "Does the test generally rank the individuals in about the same way each time?" The statistical technique of correlation is used in answering this question, and the resulting correlation is called the *reliability coefficient*. Test designers try to achieve test reliabilities above .90 but often reliabilities of .80 or .70 are useful for predicting job success. Sometimes two *equivalent forms* of a test are developed, both given to the same individuals and the correlation determined. Figure 11.10 shows results obtained with two forms of an intelligence test. It is clear that this particular test has high

FIGURE 11.10. *Scatterplot showing relationships between Form L and Form M of the Stanford-Binet Test. (After Terman, L. M., and Merrill, M. A.,* Measuring intelligence. *Boston: Houghton Mifflin, 1937)*



reliability. Tests which are too short often are unreliable, as are many tests which do not use objectively determined scores.

VALIDITY. When tests are used for selection, an essential characteristic is their *validity.* Whereas reliability refers to consistency of measurement, validity means the *degree to which the test measures what it was designed to measure.* A test may be highly reliable but still not valid. A thermometer, for example, may give consistent readings but it is certainly not a *valid* instrument for measuring specific gravity. Similarly, a test designed to select supervisors may be found to be highly reliable; but it will not be a valid test if scores made by new supervisors do not correlate with their later proficiency on the job.

When used for selection purposes, aptitude tests are evaluated by finding the degree to which they correlate with some measure of performance on the job. The question to be answered is "Does the test given to a job applicant *predict* some aspect of his later job performance?" The correlation obtained in such a determination is known as the *validity coefficient.* This is found by administering the test to unselected job applicants, and later obtaining some independent measure of their performance on the job. If the validity coefficient is a substantial one, the test may be used to predict the job success of new applicants, just as it has demonstrated it can do with the original group. If the validity coefficient is low, the test is discarded as a selection instrument, since it has failed to make the desired prediction of job performance.

Validity coefficients need not be very high in absolute value to make useful predictions in matching men to job requirements. Figure 11.11 pictures a test which was given to 1,000 applicants for pilot training in the Air Force. These applicants were allowed to go through training; six months later their proficiency was evaluated. It was found that scores on this 10-minute test correlated .36 with the performance of these individuals as pilots six months later. Figure 11.12 shows one way of representing this. Very few of those scoring highest on the test subsequently failed training, while over half of those scoring low on the test eventually failed.

Why are some tests valid and others not? The reason must be that valid tests are those which measure the kinds of abilities and skills actually needed on the job. It should be noted that tests often do not directly resemble tasks of the job, even when they are highly valid. For example, the Rotary Pursuit test shown in Figure 5.25b was found to have considerable validity in predicting success in pilot and bombardier training for the Army Air Forces during World War II. It will be recalled that this test requires the examinee to keep a metal stylus in contact with a target spot set toward the edge of a rotating disc. Often the examinees may have thought, "where does the pilot (or bombardier) do anything like this?" But the reason this

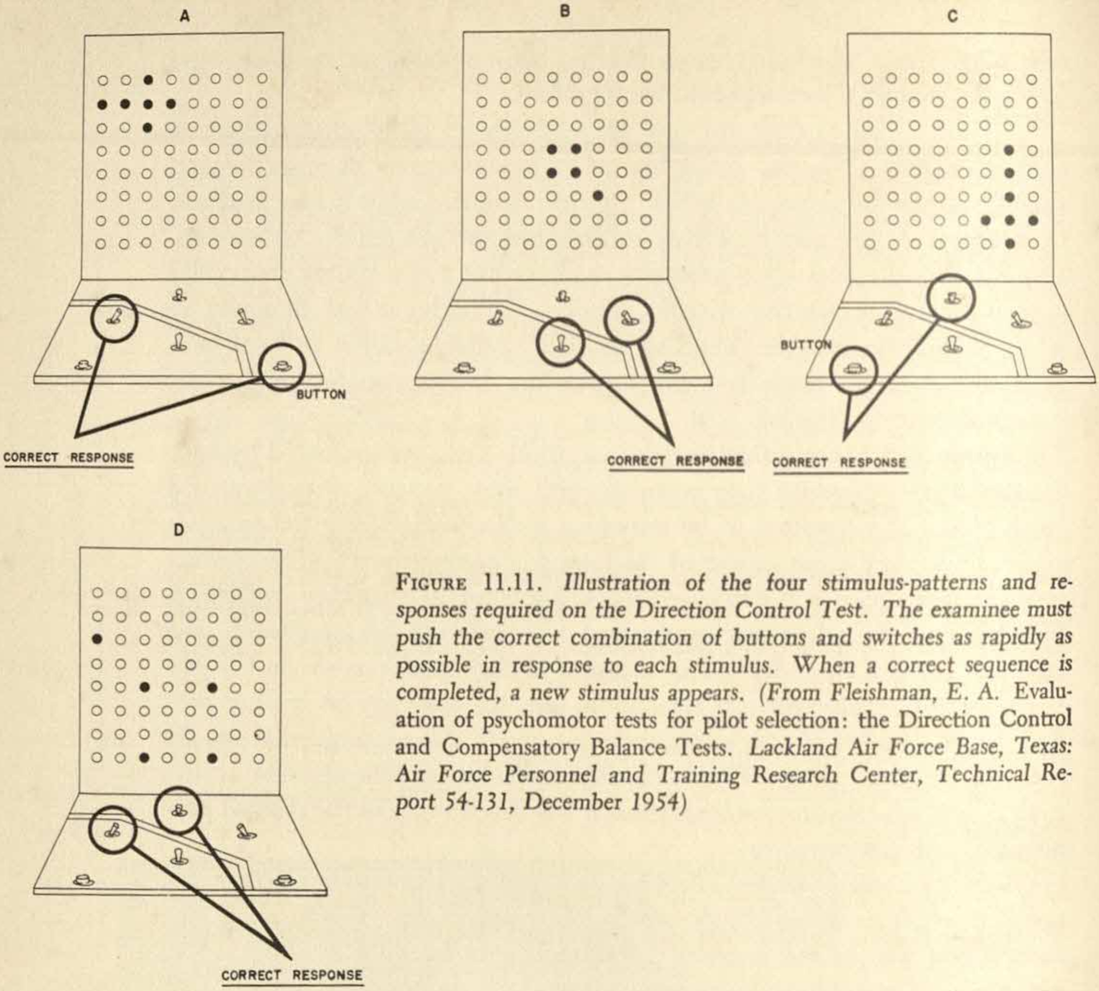


FIGURE 11.11. *Illustration of the four stimulus-patterns and responses required on the Direction Control Test. The examinee must push the correct combination of buttons and switches as rapidly as possible in response to each stimulus. When a correct sequence is completed, a new stimulus appears. (From Fleishman, E. A.* Evaluation of psychomotor tests for pilot selection: the Direction Control and Compensatory Balance Tests. *Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, Technical Report 54-131, December 1954)*

test was valid was not because of its resemblance to any task of the job, but because it sampled the *control precision* ability which facilitated the learning of these jobs. In contrast, sometimes tests which appear superficially to resemble actual tasks of the job turn out to be of low validity because they fail to sample relevant abilities.

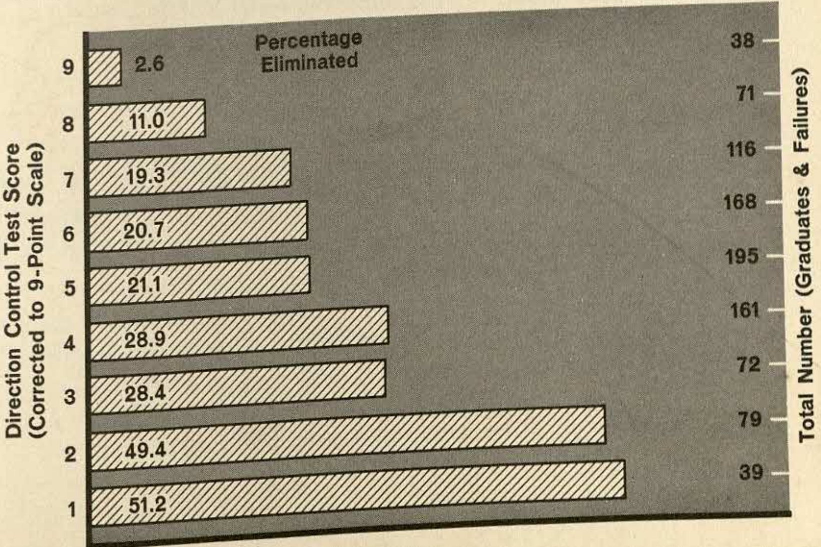
THE SELECTION RATIO. Another important factor affecting the success of selection procedures based on tests is the *selection ratio.* This is the ratio of those selected to those available for placement. If there are only a few openings and many applicants, the selection ratio is low, and this is the condition under which a selection program works best. For example, in Figure 11.12, if only a few pilots were needed relative to the number of applicants available, one could set a qualifying score of 8 on this test and there would be very few subsequent failures among those accepted. On the other hand, if practically all applicants had to be accepted to fill the vacancies, the test would not be useful, regardless of its validity, since this would amount to virtual abandonment of the selection principle. If the selection ratio is kept low, validity coefficients even as low as .20 can still identify useful tests. If the selection ratio is high, higher validities are necessary. This relationship is illustrated in Figure 11.13, using a type of scatterplot described in Chapter 5. The relationship between the selection ratio and test validity points up a kind of incidental advantage to a company of good employee and public relations. The company in which many applicants want to work can use a systematic selection program to best advantage.

Combining Tests into a Battery

Typically, when the purpose of a testing program is that of personnel selection, the program is made up of a number of tests used in combination. The reason for this is that individual differences in specific skills are usually based upon a number of different abilities. Quite often the same battery of tests is given to all applicants, when there are a number of different jobs available. Since the validities of these tests have been separately determined for each job, it may be found, for example, that tests A, D, and E predict success in job Y, while tests B, D, C predict success in job X. By the appropriate combinations of test scores it is then possible to find each applicant's "aptitude index" for job X as well as for job Y.

There are two main methods of combining scores from a test battery to make predictions of later job performance. One method is called the "successive hurdle" or *multiple cut-off* method. With this approach, appli-

FIGURE 11.12. *Relationship between scores on the Direction Control Test and the frequency of elimination from pilot training due to flying deficiency. (From Fleishman, E. A., Evaluations of psychomotor tests for pilot selection: the Direction Control and Compensatory Balance tests. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, Technical Report 54-131, December 1954)*



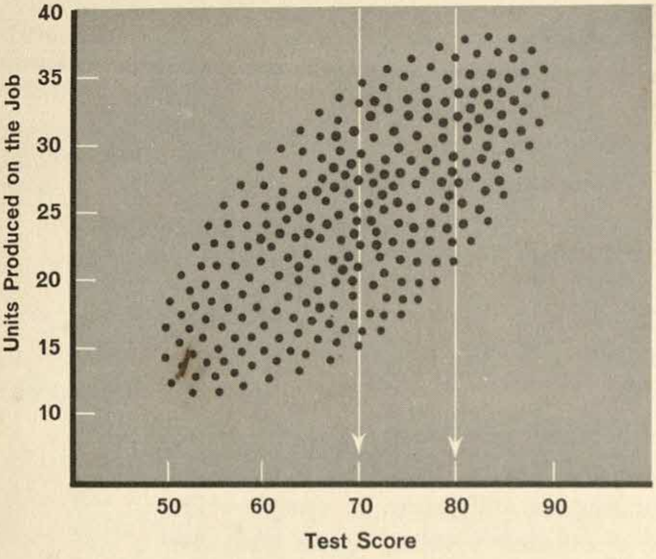


FIGURE 11.13. *The importance of the selection ratio. The scatterplot indicates that the test has a validity of about .60. If the selection ratio is low, the qualifying score on the test may be set at 80 and most workers selected may be expected to produce above 20 units. If half the applicants must be selected (selection ratio of .50), the qualifying score is reduced to 70 and the average proficiency of those selected is lowered. However, in either case, the average proficiency of those selected is considerably higher than for the group as a whole.*

cants are accepted or rejected on the basis of one test score at a time. In order to be selected, an applicant must score above a critical score on each test, and is disqualified by a low score on any one test.

The second approach uses *multiple correlation.* From the validities of the tests and their correlations with each other, a determination can be made of a proper weight for each test score. Using these weights as multipliers for test scores, a value of a total "aptitude index" can be computed for each individual. This method, then, produces a combined weighted score which reflects the individual's performance on all the tests in a battery. The particular method of combining scores which is most appropriate depends on a number of factors in the selection situation, but obviously both methods accomplish the purpose of making predictions of job success on the basis of aptitude information from a number of different tests. A comparison of the two methods is presented in Figure 11.14.

SUMMARY

Each individual displays a unique pattern of human abilities at any given time during his life. The problems of placement of men to perform human work is one of matching these unique patterns to certain definable categories called *jobs.*

For purposes of employment and placement, the great variety of individual jobs in the United States have been categorized into occupational fields and major occupational groups in the *Dictionary of Occupational*

GIVEN:

For Job X, a test of word fluency predicts success, as does a test of perceptual speed. A high proportion of those scoring below 25 on the word fluency test fail on the job; similarly, a high proportion of those scoring below 80 on the test of perceptual speed are unsuccessful.

Six new applicants for Job X make scores as follows:

A.	B.	C.	D.	E.	F.
w.f.-15 p.s.-70	w.f.-25 p.s.-90	w.f.-20 p.s.-80	w.f.-35 p.s.-75	w.f.-30 p.s.-90	w.f.-25 p.s.-85

MULTIPLE-SCREEN METHOD OF SELECTION:

Reject all applicants who score below 20 on word fluency, or below 80 on perceptual speed.

A. X	B. ✓	C. X	D. X	E. ✓	F. ✓
w.f.-15 p.s.-70	w.f.-25 p.s.-90	w.f.-20 p.s.-80	w.f.-35 p.s.-75	w.f.-30 p.s.-90	w.f.-25 p.s.-85

MULTIPLE-CORRELATION METHOD OF SELECTION:

Combine the scores of the tests into a prediction formula which weights each test score in accordance with its predictive efficiency. Such a formula might be perceptual speed + 4 times word fluency. When applied to the scores of each applicant, the results would be:

A. X	B. ✓	C. X	D. ✓	E. ✓	F. ✓
Combined Score-130	Combined Score-190	Combined Score-160	Combined Score-215	Combined Score-210	Combined Score-185

Using this method, applicant D is accepted, even though he has a relatively low score on perceptual speed. It is assumed that his high word fluency ability "makes up for" this deficiency. Such an assumption is sound for some jobs, not for others.

FIGURE 11.14. *A comparison of the multiple-screen and multiple-correlation method of selection. (Modified from* Cronbach, L. J., Essentials of psychological testing. *New York: Harper, 1949)*

Titles. This *Dictionary* classifies jobs in accordance with their membership in related groups of industrial *operations*, thus making it possible to take into account resemblances of these operations in placing men. In addition, the *Dictionary* provides basic descriptions of standard job categories.

When one is concerned with the problem of determining, from the beginning, what kinds of human abilities are required for a particular set of jobs in a plant, office, or factory, one must begin with a particular *job description*. The major elements of a job description are called *tasks*, and each of these is the smallest unit of operation that would normally be assigned to one man. Task descriptions ideally provide complete, understandable, and dependable accounts of the operations required, and thus form the basis for analysis of human abilities.

Job analysis is the process of preparing job descriptions and inferring required *human skills and abilities*. The job analyst determines the kinds of discriminations, identifications, sequences, motor skills, concepts, decisions, and problem-solving activities necessary for the performance of the operations which have been described. These determinations of *specific skills* then form the basis for decisions about *selection and training requirements*. The analyst makes additional estimates concerning the *abilities* and *interests* which appear to support the learning of these specific skills, and these estimates form the basis of a *selection* program.

Personnel selection techniques fall into the three major categories of *psychological tests*, *application blanks*, and *interviews*. Tests of various types are designed to measure human abilities, personality traits, and interests. Successful use of tests in selection depends on the *standardization* of testing conditions and on the use of *norms* for interpretation of *raw scores*. Two of the most important test characteristics are *reliability*, an indication of how dependably the test measures, and *validity*, which is the degree to which the test predicts the performance it is designed to predict. Several tests are often combined into a test *battery*, in order to sample a wider range of abilities. When this is done, some method of combining test scores must be employed in making the prediction of job success.

READING REFERENCES

See Reading References following Chapter 12, page 392.

12

JOBS AND PERSONNEL SELECTION, II

This chapter continues our description of methods of personnel selection. Then we turn to the important matter of assessing human performance, and examine some ways that are used to measure the quality of performance in working situations. You will see that this is an essential part of the entire process of matching men and jobs.

In the last chapter we saw how tests are used to select personnel. Now we turn to a consideration of the two other methods of predicting success in a given type of work: the application blank, and the employment interview. Following this, we shall describe the process of evaluation of individual proficiency on the job.

THE APPLICATION BLANK

The application blank and the employment interview are almost universally used in personnel selection, and they are frequently used in combination. We shall first examine the application blank and how it is used in selection programs.

Content and Method of Use

The application blank contains questions about the past history and personal life of the individual applicant. The rationale of its use is that items of personal history (such as facts about previous experience and interests) are predictive of the applicant's future success on the job. Many application blanks currently in use appear very long and tedious to fill out. Actually, the most successful use of such blanks occurs when the characteristics to be covered are those which have been shown by job analysis to be requisites for good job performance.

As used in personnel selection, the application blank is usually reviewed as a whole by an employment interviewer. This procedure obviously involves a great deal of "subjective" judgment on the part of the interviewer. Consequently, its success depends not only upon the accuracy of the job description used as a reference, but also upon the skill of the interviewer and his knowledge of the validity of individual items of the blank.

In many employment situations, the application blank can be of great value in personnel selection. Such personal history items as age, number of dependents, years of education, previous earnings, amount of insurance held, may be related to later proficiency on the job, earnings, length of tenure, or with other criteria of job success. The problem is one of discovering which items differentiate workers who score high from those who score low on the performance to be predicted. To do this, such factors as age, education, previous experience, and interests are correlated with later job proficiency. Items which correlate highest receive the greatest weight in judging the probable success of later applicants.

WEIGHTING ITEMS. An example of the procedure followed in determining validities and weights for application blank items comes from a study in which such a blank was used to select secretaries. The objective was to develop a way of scoring the application blank to select secretaries who were most likely to remain on the job two years or more. In other words, the blank was to be used as part of a program of selection designed to reduce turnover.

The first step was to find out which items differentiated short-tenure and long-tenure employees who had been hired at about the same time. Sixty secretaries who were still on the job after two years were termed the "long-tenure" group, while sixty secretaries who had left before two years were called the "short-tenure" group. Their original applications were examined and a comparison made of their responses. Table 12.1 gives some examples of items which did and which did not differentiate these two groups. It can be seen, for example, that local address was a good "differentiator," but

TABLE 12.1
COMPARISON OF RESPONSES TO BIOGRAPHICAL ITEMS MADE BY SHORT-TENURE AND LONG-TENURE SECRETARIES

	Percentage of:		
Application Blank Items	*Short-tenure group*	*Long-tenure group*	*Weight Assigned to Response*
Local address			
within city	39	62	+2
outlying suburbs	50	36	−2
Age			
under 20	35	8	−3
21-25	38	32	−1
26-30	8	2	−1
31-35	7	10	0
35 and over	11	48	+3
Previous salary			
under $2,000	31	30	0
$2,000-3,000	41	38	0
$3,000-4,000	13	12	0
over $4,000	4	4	0
Age of children			
preschool	12	4	−3
public school	53	33	−3
high school or older	35	63	+3

(From Berniger, J. and Fleishman, E. A. A weighted application blank for reducing turnover among secretaries. Unpublished report, 1958.) A negative weight indicates this response favors short tenure. Size of the weight indicates the relative difference between the groups. Weights ranged from −3 to +3.

previous salary was not. Certain responses to the question of age also distinguished the groups. Some other items which tended to differentiate were "reason for leaving last employment," "occupation of husband," and "number of children."

The next step was to assign actual "weights" to the items. Items which did not discriminate were weighted zero (in other words they were not counted). Some responses were weighted negatively, others positively. Thus, a response of an address in the suburbs was scored negatively, but one in the city scored positively. Similarly, age "over 35" received a positive weight, but "under 30" received a negative weight. Next the size of the weight was determined. Items that showed a bigger difference between the long- and short-tenure groups were given a higher weight; for example, age under 20 was weighted −3, whereas age 26-30 received only a −1 weight. To find an applicant's score on the total application blank,

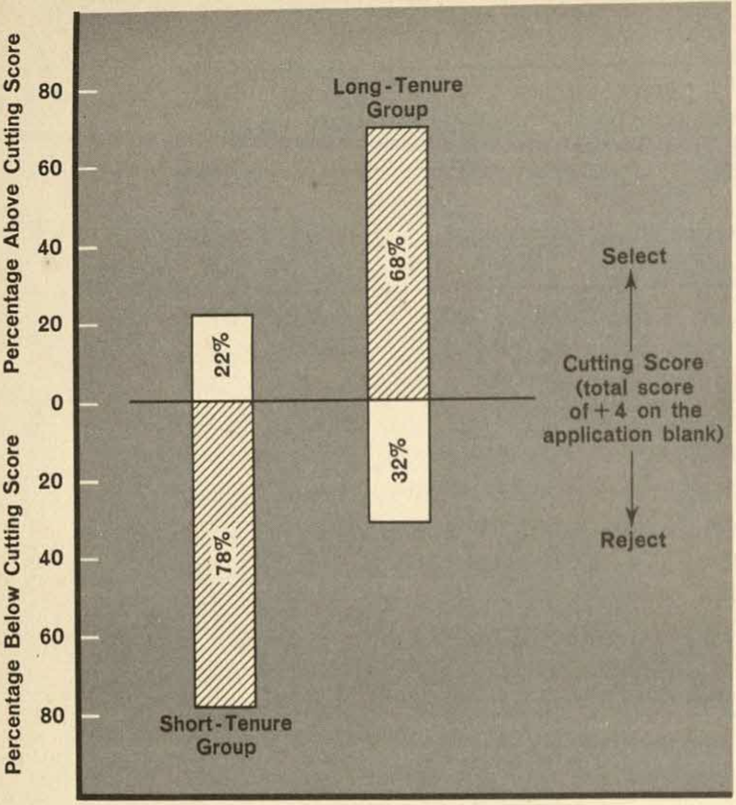


FIGURE 12.1. The value of a weighted application blank for reducing labor turnover among secretaries. The shaded areas represent the percentage of correct hiring decisions and the unshaded areas represent the percentage of incorrect hiring decisions. (From Berniger, J., and Fleishman, E. A., A weighted application blank for reducing turnover among secretaries. *Unpublished report, Yale University, 1958)*

the algebraic sum of all the weights was then obtained. In this study the range of these scores was found to be −17 to +27 in a group of applicants.

Before the blank could be used on new applicants it was tested to see how highly total scores correlated with the *tenure* of another group of secretarial applicants. This correlation was found to be .57. The final step was to set a "cutting score" which the personnel department might use routinely to select or reject applicants. Figure 12.1 illustrates the degree of success, for 85 secretaries subsequently hired, if a cutting score of +4 were used. The blank would have successfully picked 2 out of 3 of the employees who stayed more than two years, and would have rejected approximately 4 out of 5 of those who did leave before two years.

Uses of the Application Blank

The above example shows how the application blank can be used for predicting turnover, a use which is of value in selecting people for positions which require long, costly training or where turnover is especially high. Weighted application blanks are also used successfully to predict accident criteria and proficiency criteria. They have been particularly effective in sales jobs, and they have also shown validity for selecting Army officers, Air Force pilots, cab drivers, executives, and clerical workers. It should be emphasized here that there are no biographical items which work for all criteria of performance or for all jobs. Instead, each blank must be "tailor-made" for a particular job. For example, a blank used successfully for years to select life insurance salesmen was found to have low validity in selecting salesmen of other types of insurance working within the same company.

It is sometimes hard to tell why certain items in the application blank predict well while others do not. Probably answers to questions on the blank reflect the individual's motives, abilities, skills, level of aspiration, and adjustment to working situations. Thus, the most useful information is likely to be an individual's record of past jobs, specific skills (e.g., typing, machine operation), education, financial status, marital record, the number of different jobs held, and similar data. The fact that an individual has held a similar job indicates the likelihood of some transfer of training to a new job. Similarly, what the individual has successfully done before is likely to reflect his basic abilities for learning these skills, as well as his interest in and satisfaction from such activities.

In many selection procedures a score derived from the application blank is combined with scores made by the same applicants on psychological tests. In such cases the score is treated like scores from other tests combined into a battery, as in the methods previously described.

THE EMPLOYMENT INTERVIEW

The interview is the most widely used, but the least well validated, selection technique. Although employment officers often have intense faith in the interview, rarely is it subjected to the careful scrutiny applied to other selection methods, such as tests. A number of studies show that information obtained through the interview is often inaccurate, that experienced interviewers often disagree markedly in their evaluation of applicants, and that the interviewer's judgment is often influenced by irrelevant physical and superficial characteristics of the applicant. Other studies have shown zero correlations between interviewer evaluations of applicants and their later job success.

The employment interview has some functions besides that of selection. For example, from it the employee obtains information about the company and about the job. The interview has a public relations objective, and tends to make the company seem "more personal" to the applicant.

Turning to the use of the interview in personnel selection, it is often difficult to evaluate the contribution of the interview to the selection process, because it is so frequently used in combination with other methods. Thus, one interviewer may have available an applicant's test scores and application blank, while another may rely mainly on his judgment based on the face-to-face conversation. Generally speaking, however, the more the interviewer relies on additional, objective sources of information, the better prediction he can make about the future success of the applicant.

How can the interview be improved as a selection method? In order to answer this we need first to examine some of the difficulties and shortcomings in many employment interviews.

Some Sources of Error in Interviewer Judgments

Many of the inadequacies of the employment interview may be traced to the inadequacies of human judgment. There is, for example, the common error of *halo effect*, which has been demonstrated many times and studied extensively. This error is the tendency to rate an individual either high or low in many traits based on the rater's impression of some particular trait. There is a tendency for the interviewer to approve of one trait and to carry

TABLE 12.2
PERSONAL TRAITS LISTED AS OBJECTIONABLE BY THREE EMPLOYMENT INTERVIEWERS

Interviewer A	*Interviewer B*	*Interviewer C*
Biting fingernails	Chewing and snapping gum	Short arms
Talking with cigarette in mouth	Being jittery or fidgety	Bad breath
Interrupting you	Non-stop talking	Shifty-eyed
Playing with articles on person	Too aggressive	Too well-groomed
Smoking chain fashion	Loud clothing	Sloppy
Being pretentious or bragging	Not meticulous about personal hygiene	Ugly
Using "I" continuously	Mousy and bashful	Jiggling legs continuously
Inconsideration	Fresh and "smart-alecky"	Tapping
Avoids looking you in the eye	Making gestures with hands	Doodling
"Alibi"	Foreign-looking	Acne

(From American Management Association, *Manual of Employment Interviewing*, Research Report No. 9, 1946.)

this over to his total judgment of the applicant. For example, a man with a pleasant manner may be judged as generally proficient, or a tense individual may be thought of as lacking initiative.

Stereotypes represent another type of error. Redheads are *not*, on the average, more hot-tempered than other people. A weak chin does *not* indicate a weak character. A number of different racial and national stereotypes are known to be invalid. Yet it has been shown that biases of this sort do influence judgments made in the interview situation. Table 12.2 presents an interesting study of traits considered "objectionable" by three employment interviewers in the same company. It is doubtful that these traits could be related to job success, especially since the interviewers do not agree among themselves.

Lack of rapport is another problem in the employment interview. By "rapport" is meant the establishment of a relationship of mutual confidence. Without this, communication problems develop between the interviewer and the interviewee, and the results of the interview become less reliable. Judgments about tense or suspicious interviewees, arising from lack of rapport, may not be relevant to later job behavior.

The Patterned Interview

Many of the limitations of interviews stem from the haphazard way they are sometimes conducted. Often there is little planning, organization, or direction to interviews, and the topics covered in them may vary from one applicant to the next. The reliabilities of such procedures have been checked by having different interviewers interview the same applicants, and then finding the correlations between ratings. These correlations are usually close to zero. Another factor contributing to the unreliability of interviews is that they are frequently too short. A nationwide study of business practices indicated that the average employment interview was less than 10 minutes long.[1] Obviously, when the sample of behavior on which predictions are to be based is not very large, reliability is accordingly low.

These shortcomings have led to increasing use of the *patterned interview* (sometimes called the structured or standardized interview). The basic characteristics of this procedure are that the interviewer works from the job description, he has a definite plan, he has been trained, and he uses many other sources of information about the applicant. Frequently he fills in a printed form, which may contain rating scales to be checked for various applicant characteristics. The validity of the items included in such an interview needs to be determined as is done with tests and application-blank items.

The successful interviewer uses as many sources of information as possible. One of these sources is *job analysis,* which includes the job description and the skill and ability requirements. The *application blank* is another, which not only serves as a basis for establishing "rapport" in the beginning of the interview, but also eliminates the need to ask for information already elicited in the blank. *Aptitude* and *proficiency test* records are an additional source. *Oral trade tests* are also available to the interviewer, and may be used to test an applicant's knowledge in a given occupational area.

The interview should not attempt to evaluate abilities and skills for which better measures are available. For example, in the assessment of "intelligence," clearly the best measures are available in objective tests which are relatively easy to administer. An interviewer would probably not attempt to measure physical fitness; similarly, many other abilities can best be measured by other means, particularly by tests. But poise, physical appearance, speech control, and sociability may be more suitably appraised in the interview than in any other way.

Training the Interviewer

The training of interviewers usually works to increase the reliability and validity of their interviews. The halo effect, stereotype errors, and problems of rapport can be reduced by training. Table 12.3 summarizes some procedural points to be covered in interviewer training programs.

TABLE 12.3
WAYS TO IMPROVE THE EMPLOYMENT INTERVIEW PROCEDURE

Have a plan, made in advance (use a check list or form).
Have adequate job knowledge (review job analysis data).
Have adequate background information on the applicant (application blanks, references, test scores, etc.).
Schedule enough time (maintain an unhurried atmosphere).
Assure privacy.
Put applicant at ease.
Discount initial impressions.
Let applicant talk (within limits); Listen!
Avoid leading questions.
Adjust language level to ability of applicant.
Keep control of the interview (don't digress or ramble).
Be aware of one's own prejudices.
Know how to close the interview.
Record impressions immediately after interview.

(Adapted from Bingham, W. V., and Moore, B. V., *How to interview* (3rd edition) New York, Harper & Bros., 1941.)

EVALUATION OF JOB PROFICIENCY

We have now seen how a set of operations can be divided into jobs, the required human skills and abilities identified, and individuals selected to fill the jobs. *Training*, which is used to establish the particular job skills required, will be the subject of the next chapter. Meantime, we turn here to a consideration of how one answers the question: How well are the individuals who have been selected (and trained) actually performing in these jobs?

The job description states what the incumbent is expected to do. It therefore provides the categories of behavior within which a job incumbent's performance may be evaluated. But it does not provide standards for *quality* of performance. This assessment of the quality of performance is what is meant by evaluating job proficiency.

The assessment of proficiency of individual workers in particular jobs is important to industrial operations for a number of reasons.

1. Information about job proficiency is used to *evaluate the effectiveness of selection procedures.* These measures represent the *criteria* for evaluating the validity of the tests, application-blank items, and interview judgments.

2. Job proficiency measures are used to *evaluate training programs.* In order to observe the benefits of training one needs to observe a change in some measure of job proficiency. Such information may also be used to determine the needs of individual job incumbents for specific kinds of additional training.

3. The plant manager or production chief must know what the capabilities of his personnel are, just as he needs to know the capabilities of the mechanical parts of the production system. Assuming that John Q and Harry X are working as mechanical inspectors, what is their expected output under certain specified conditions of work?

4. The manager needs to know about individual job proficiency in order to take certain *personnel actions,* such as promoting or separating individuals from employment, or transferring them to related or higher-level jobs.

5. Such information may also be used in *salary administration* such as that involved in determining wages, piece rates, and bonuses for individual workers.

6. Measures of job proficiency may be used to compare the effectiveness of different departments in the organization, or different *methods and conditions of work.*

TYPES OF PROFICIENCY MEASURES

The assessment of job proficiency has been done in a number of ways, some of which are more readily applicable to some jobs, some to others. In some cases, assessment is made by measuring the individual's *performance of an operation,* while in others, the underlying *skills and knowledge* that give him the capability of performance are measured. For example, a job description may contain statements of the tasks which describe the operation to be performed, such as "Inspects gimcrack shaft to measure 1.25 inches ± 0.15 OD." Other statements specify the concepts needed as a prerequisite to performance, such as the "rule for subtraction." The assessment of proficiency, accordingly, could be based upon a measured level of performance of the task as stated; or it could be a measurement of whether the individual knew the rule for subtraction (and other required concepts). Whenever possible, it would seem better to assess actual performance, since fewer assumptions are being made. However, the second method is sometimes resorted to, in the attempt to overcome the difficulties and expense of obtaining actual performance measures. The fact that assessment of skill or knowledge represents a *derived,* and therefore an *intermediate,* criterion of job proficiency should be recognized. There are also instances in which it is not feasible to obtain objective indices of either performance or skill. In such cases, *rating techniques* are often used.

We shall consider first some techniques of performance measurement, including production records and performance tests. Following this, we shall examine job-knowledge tests, and finally, some rating methods.

Production Measures

In some operations, job proficiency can be evaluated directly in terms of amount and quality of work. This is particularly true when the job consists of tasks which are frequently repeated. Some measures which have been used for production-line jobs include number of pieces turned out per day, amount of output (in pounds, units, or dollars), and number of rejects (units failing inspection). In sales jobs, number of sales and dollars of sales are often used. In the transportation industry a variety of measures have been utilized such as number of collisions with vehicles, number of collisions with people, number of traffic violations, number of complaints, and broken schedules. Production records of these types, when used to assess individual proficiency, must possess two essential characteristics. First, the task must be repeated frequently enough during the measurement period to insure high reliability of the measure; in other words, there must be a reasonably high correlation between production on one day and production on another. Second, the conditions need to be such that performance differences are not due to factors beyond the control of the job incumbent, such as machine differences or assembly-line pacing.

There are two main problems to be solved in using production records to evaluate individual proficiency. One is how to combine different possible measures (for example, quantity and quality) in the most meaningful way. The other is the problem of comparing individuals who do not work under comparable conditions. We shall illustrate these in turn.

COMBINING DIFFERENT MEASURES. Sometimes it is difficult to decide on one single production measure as the most important. Thus, for bus drivers, number of accidents is important, but so is "keeping on schedule." It is possible to *weight* one more than the other, just as test scores are weighted.

Weighting output in terms of sheer quantity may not be an adequate measure of proficiency unless each unit produced meets some standard of "correctness," or quality. If two typists each turn out fifty letters per day, but one set of letters contains a total of 100 errors, while the other has only 10 errors, there is a considerable difference in the proficiency of these two people which may be important for the job. Similarly, if we wish to use "pounds of butter wrapped" as a proficiency measure, we have to specify that each pound be wrapped "correctly," or in conformity with some inspection standard of quality. Because of this, any proficiency score derived from a measure of output needs to be weighted in some way which takes quality into account.

The determination of how to weight production scores for quality usually involves a judgment of the importance of quality, or of errors, to the operation being performed. In the simplest case, a unit of output which fails to meet a quality standard may be simply subtracted from the total output, under the assumption that this unit simply has to be redone. For

TABLE 12.4
PROFICIENCY SCORES OF FOUR WORKERS OBTAINED BY WEIGHTING OUTPUT MEASURES FOR QUALITY

Individual Worker	*Units Produced*	*Units Rejected for Quality*	*Weighting (−1)*	*Proficiency Score*	*Weighting (−3)*	*Proficiency Score*
A	100	7	−7	93	−21	79
B	120	7	−7	113	−21	99
C	100	14	−14	86	−42	58
D	120	24	−24	96	−72	48

example, if the wrapping of a pound of butter is defective in quality, this simply means that another pound has to be wrapped to take its place. Consequently, this unit may simply be subtracted in the obtaining of a proficiency score; its weighting may be said to be −1. Table 12.4 shows how the proficiency scores of four workers would be obtained in this case. Notice that Worker A attains a proficiency score lower than Worker B primarily because A produces fewer units than B, although both have the same number of quality rejects. Although Worker D has many more rejects than Worker A, he too obtains a higher proficiency score because he produces more units than A. On the other hand, should it be decided that rejected units are to be weighted −3, quite a different set of proficiency scores are obtained for the same set of workers, as shown in the final two columns.

How much to deduct is best determined by actual study. For example, in the job of punching IBM cards, it has been found that correcting an error takes as much time as punching 14 additional cards.[3] For this job, productivity records are diminished by 14 for each error. Thus, an individual who punched 228 cards in 1 hour, with two mispunches, would be operating at a 200 card per hour output. In another job, a hosiery producing operation, it was determined that "imperfects" generally sold for 25 percent off. In this case, a worker might be credited for ¾ of a unit produced for each imperfect stocking.

FINDING COMPARABLE UNITS OF PRODUCTION. Individuals doing the same job may work at different hours, in different departments, or with somewhat different machines. Similarly, workers in one department may make a somewhat different product, although the general skill level and type of work is the same. Suppose, for example, that Mr. Jones in Job A is assembling small relays and completes 50 per day; Mr. Smith in Job B is assembling large relays and does 16 a day. Which is the more productive worker? One way of making this comparison is to use standard scores (see Chapter 5). For example, suppose the average output for all workers in Jobs A and B are 40 and 10 respectively. This means that both workers are above average in production. However, in order to compare them in terms of comparable units, we must know the variability or the standard deviation of their respective groups. It turns out that the standard deviation for Job A is 10 and for Job B, 3. We can now compare the productivity of Mr. Jones and Mr. Smith in terms of Z-scores, where $Z = \left(\frac{x-M}{S.D.}\right)$. Mr. Jones' Z-score is 1; in other words he is one standard deviation above the mean. Mr. Smith's Z-score is 2. Thus, we may regard Mr. Smith as having the greater proficiency.

Performance Tests

In many instances extraneous factors affecting productivity on the job are too great to be controlled, so that the resulting measure does not meet the requirement of adequate reliability. For example, in automobile driving, the task of backing up a hill may occur with such relative infrequency that we should need to measure a driver's performance for many weeks in order to obtain even one example of this task. On the other hand, the task of executing a left turn may occur with fair frequency, but under such a wide variety of road conditions for different drivers that we could not readily employ such a measure for comparison of one driver's performance with another without an extensive study to equate the "left-turn" performances under these different conditions.

The most straightforward solution to this difficulty is to devise a standardized *performance test*, sometimes called a *job sample test.* Such a test is designed to provide reliable measures of the performance of representative job operations under controlled conditions. We can overcome the infrequency of occurrence of the task of backing up a hill, for example, by including it as an item in a performance test which puts each driver "through his paces" on a number of driving tasks including this one. We can also include items for executing a left turn which are reasonably standard; that is, which represent nearly identical conditions for each driver.

Performance tests for automobile drivers are of course in wide usage Generally, they attempt to assess the performance of a driver in such tasks as starting the car, putting the car in motion from a stop, slowing at intersections, executing a right turn, executing a left turn, parallel parking, and so on. Some of these tests, or "road-checks," are better than others in accomplishing their purpose of proficiency measurement.

CHARACTERISTICS OF A GOOD PERFORMANCE TEST. The two main characteristics of a successful performance test are *representativeness* (sometimes called "content validity") and *reliability.*

The designer of a performance test selects, from the total list of tasks that make up the job, a *representative* set which can be used for the test. Obviously, it will not usually be practical to measure the individual's performance on each and every task, since this would take a great deal of time. Hence the need for selecting items. Each item so selected should represent an important part of the total job. Furthermore, the whole set of items which make up the test should reflect the relative importance of the operations in the job itself. For example, the job of maintenance man for a radar set may require the operations of *checking, adjusting and aligning, finding malfunctioning parts, and removal and replacement of parts.* A perform-

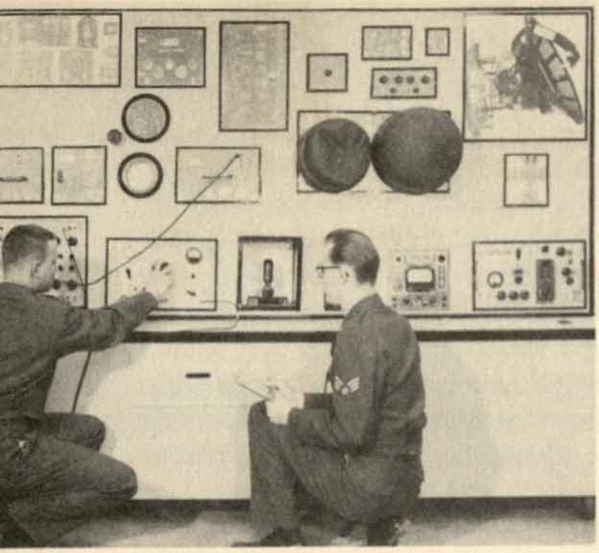


FIGURE 12.2. *A performance test for assessing performance of radar mechanics in the tasks of checking, adjusting, and aligning. (From Bernard, G. G,. and Briggs, L. J.,* Comparison of performance upon the E-4 Fire Control System Simulator and upon operational equipment. *Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, Research Report AFPTRC-TN-56-47, April 1956)*

ance test for this job should certainly include items representative of each of these operations. In addition, it may be decided that *finding malfunctioning parts* is a somewhat more important part of the total job than is *checking*. If so, the designer of the test might want to include more items on malfunctions than on checking. No absolute rule can be given for the determination of the relative importance of parts of the total job. This is a matter of the degree of essentiality of operations, not of the difficulty of human performance.

Figure 12.2 shows an example of a performance test designed to measure the activities of checking, adjusting, and aligning airborne radar equipment. The radar mechanic whose performance is being checked carries out a representative set of these tasks, using the test equipment provided. The observer records the performance of each mechanic, in terms of time and errors. This performance test provides a standard situation yielding scores which make possible the comparison of mechanics' performances.

The error to be avoided by insisting on representativeness of items for performance tests is that of choosing items on the basis of convenience or simplicity of measurement. In the example just given tasks involving *checking* may take less time and be easier for an examiner to observe than tasks requiring *alignment* of circuits. The temptation therefore would be to construct a test with many checking items and few alignment items. Obviously, such a test would be unrepresentative.

As with other types of tests, *reliability* of performance-test measures is of course needed, because one must be able to insure that the score obtained is reasonably dependable. Reliability may be measured by correlating the measure obtained on one occasion with that obtained on another, or by correlating measures from alternate forms of the performance test.

Situational Tests

A recent development in the field of performance testing is the use of *situational tests* to evaluate leadership performance and group effectiveness. At the end of a training program, supervisors seated around a table may be presented with a realistic problem such as "selecting a new plant site." Discussion proceeds, and trained observers record the problem-solving or leadership behavior of various participants. The military services have used such evaluation programs for officer candidates, who must work in teams in negotiating obstacle courses presenting realistic problems (for example, how to get a group of men over an odd-shaped wall or across a ravine). Standardized group performance tests have also been developed to evaluate the proficiency of combat teams. These are usually carried out in simulated maneuvers under highly realistic conditions where a standard amount of "ammunition" is provided, along with maps, standard enemy attacks, etc. Umpires evaluate various aspects of group performance. To be used successfully, these techniques must meet the same standards of reliability and validity as do other tests.

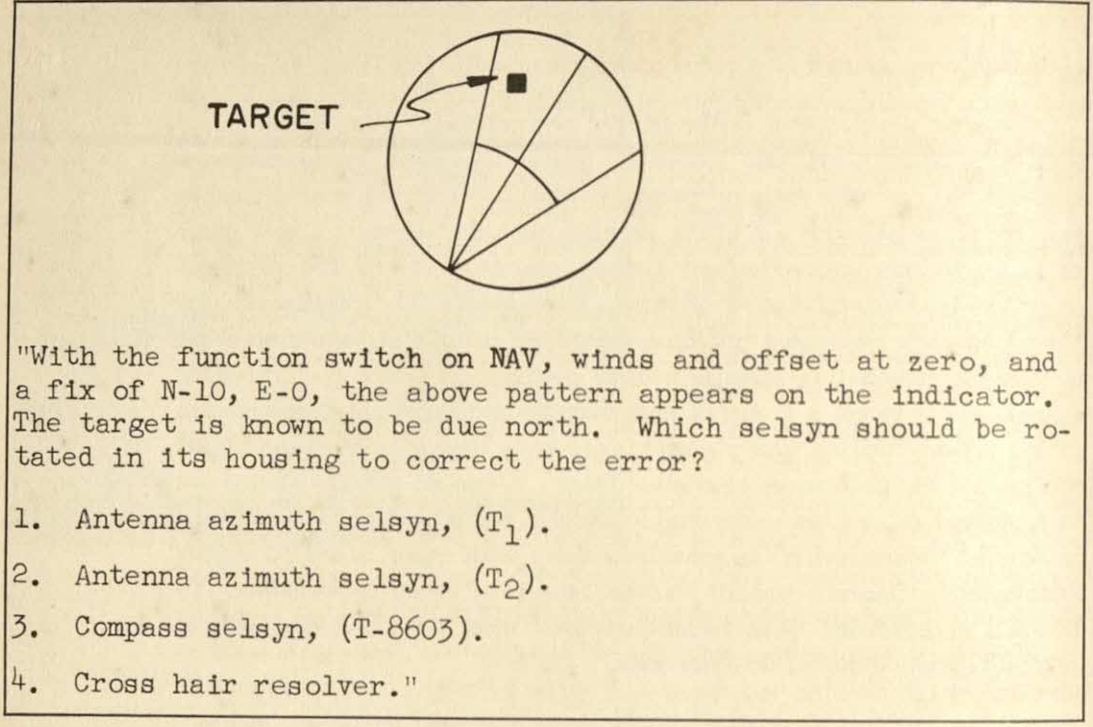
Job-Knowledge Tests

Although production measures and performance tests are greatly to be preferred to other possibilities in the assessment of performances of individuals in jobs, tests of *job knowledge* are frequently employed because of their relative inexpensiveness and convenience of administration. Such tests remove the measurement of proficiency one step farther from the criterion of operational success. The basic assumption is made that if an individual possesses the required *knowledge* he will in fact be able to exhibit the required *performance*. This assumption is not always justified. One reason is that performance is a function of motivation as well as knowledge, as we have seen in Chapter 4. In other cases knowledge may be a prerequisite, but may actually represent only a small proportion of total proficiency, as in the case of decision-making skills or motor skills.

Trade tests represent one kind of job-knowledge test. For example, the following items, among others, were used to evaluate proficiency as a cook:

1. What do you put on fried sweet potatoes to make them brown? (sugar)
2. What vegetables are used in succotash? (beans and corn)
3. What kind of meat is used in Irish Stew? (lamb)

Such tests as these, however, measure only a limited portion of the knowledge required for the job. Much more sophisticated forms of job-



"With the function switch on NAV, winds and offset at zero, and a fix of N-10, E-0, the above pattern appears on the indicator. The target is known to be due north. Which selsyn should be rotated in its housing to correct the error?

1. Antenna azimuth selsyn, (T_1).
2. Antenna azimuth selsyn, (T_2).
3. Compass selsyn, (T-8603).
4. Cross hair resolver."

FIGURE 12.3. *An item from a job-knowledge test for the job of radar-maintenance technician. (From Demaree, R. G., Crowder, N. A., Morrison, E. J., and Majesty, M. S.,* Proficiency of Q-24 radar mechanics: I. Purposes, instruments, and sample of the study. *AFPTRC Research Bulletin TR-54-50)*

knowledge tests are designed to make a comprehensive coverage of the elements of knowledge required for a particular job. The specific knowledges required for all tasks of the job, as revealed by job analysis, must be sampled in the test. A sample item of a job-knowledge test of this type, applicable to a radar technician job, is shown in Figure 12.3.

The characteristics of reliability and representativeness also apply to job-knowledge tests. In addition, it is often possible to find out if the particular knowledges tested relates to actual performance. If the test shows good validity when correlated with job performance, one has greater confidence in using the test as an intermediate measure of proficiency. The validity of job-knowledge tests also provides a check on the correctness of the job analysis.

Rating Methods

If one is concerned with assessing the proficiency of an individual in performing a job, one of the methods which may first be thought of is "Ask his supervisor." In some instances, particularly those involving small numbers of employees, this may be a very good method indeed. The supervisor may be able to say immediately, "John Jones does sloppy work; James Burns is extremely accurate but somewhat undependable; Joe Smith turns out work steadily and dependably." In other words, the supervisor may respond with a word-picture which identifies the outstanding qualifications, good and bad, of each individual concerned.

When many employees are involved, however, it may be desirable to try to achieve considerably greater precision of measurement than that provided by this simple example. Suppose a manager employs 60 stenographers, who work under 12 different supervisors. He wants to select the best two for promotion. A collection of statements from their supervisors would probably yield word-pictures showing little distinction between individuals. Because of this, it is desirable to use some standardized method of *ranking* or *rating* which will comprehensively cover all aspects of the job. In ranking, the supervisor (or other judge) is asked to place all the individuals under his supervision in order of rank from "best" to "worst." In rating, the supervisor is required to judge each individual's ability with respect to a scale representing degree of ability from low to high.

The use of standardized methods of rating is beset with certain difficulties which limit the usefulness of the proficiency estimate obtained. These difficulties are much the same as those discussed previously in connection with human judgment in the employment interview. These include the *halo effect, personal biases,* and *stereotypes* as well as certain *constant*

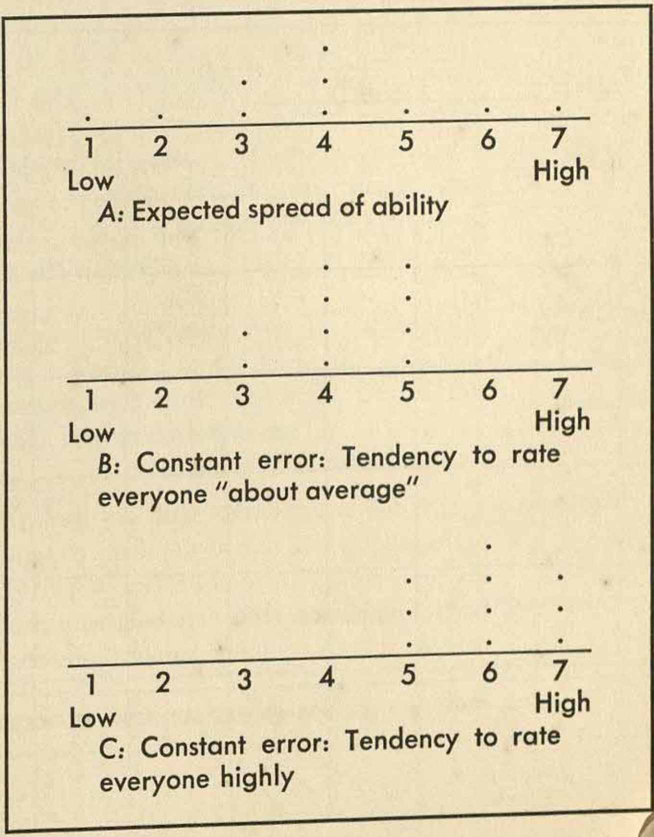


FIGURE 12.4. *Constant errors in a seven-point rating scale.*

errors. In the last category are errors of "leniency" (the tendency to resolve misgivings by giving the benefit of the doubt) and errors of "central tendency" (the tendency to rate everyone about average). Figure 12.4 shows the operation of three types of errors made by raters. Whereas the intention was to distinguish between seven different levels of rated performance, only three levels were actually obtained. Various methods are used to overcome these weaknesses, insofar as this is possible. Supervisors who are aware of the difficulties involved and who have been trained to avoid them are better able to use rating methods successfully.

Types of Rating Methods

Rank Order. In the rank-order method each supervisor places all of his men in order of merit, from the highest to lowest. This may be done on the basis of his "over-all" job performance, or it may be done for several job operations separately (e.g., inspecting, assembling, etc.). An individual's proficiency score is simply the average rank assigned him for all characteristics rated. Figure 12.5 illustrates the method used to rank six employees on four characteristics frequently used on industrial forms. It can be seen here that worker Bill rated best, while Mike received the lowest rank. The system used eliminates constant errors such as errors of leniency and

FIGURE 12.5. *An example of the method of rank order applied to merit rating.*

Rater: ____________________

	Employee rankings					
	Joe	Bill	Tom	Bob	Fred	Mike
Quantity of work	2	1	4	3	6	5
Quality of work	5	2	1	6	3	4
Initiative	3	1	2	4	5	6
Compatibility	1	3	2	5	4	6
Total	11	7	9	18	18	21
Average rank	2.7	1.7	2.3	4.5	4.5	5.3

central tendency but does not avoid the halo effect or personal bias. Figure 12.5 shows the probable occurrence of halo effect in these ratings.

The rank order is useful where raters are untrained in appraisal techniques, and where there are only a few individuals to be ranked. If there are twenty or more individuals the system tends to be cumbersome. In addition, it will readily be seen that the magnitude of differences in proficiency between ranks is not equal at different positions. Thus the differences between rank 3 and rank 4 may be large in some departments or small in others. In fact, the primary limitation of this method lies in the fact that it does not make possible comparisons of ratings from one group to another. Knowing that two men are each ranked first in two departments provides little information about their comparative merit.

PAIRED COMPARISONS. This is an adaptation of the rank-order method which requires the supervisor to compare only two people at a time. Often the supervisor may find a straight ranking difficult to make, when there are as many as 15 or 20 men. In this method, he is presented with two names to a card, and goes through the cards comparing each man with every other man an equal number of times, checking the name of the man he believes is the better in each case. This method, of course, requires the supervisor to make many more judgments, and is tedious for big groups. The number of comparisons is always equal to $\frac{n(n-1)}{2}$ where n is the number of individuals rated. If there are 20 men in the total group, the supervisor must make 190 comparisons. If there were 100 men to be rated, the number of comparisons would be 4,950! In this method, an individual's score is computed as the number of times he was chosen in all comparisons.

GROUP-ORDER RANKINGS. A further adaptation of the paired-comparison technique, sometimes used in large departments, is illustrated in Figure 12.6. Here the supervisor is asked to assign a definite proportion of individuals to each of several categories, or to a number of characteristics. Often the proportion specified for each ranking is roughly in accordance with normal curve probabilities.

RATING SCALES. Rating scales require the supervisor to indicate the position of an individual, usually with respect to some particular aspect of performance, along a defined scale ranging from low to high. One of the simplest examples is a numerical scale, such as the following:

Effectiveness in
speaking to small
groups: 0 1 2 3 4 5 6 7 8 9 10

The rater may check a series of such statements. The individual's total rating is taken to be the sum of the checked values.

Rate each worker in your department. First rate them all on the first characteristic, Amount of Output, then rate all of them on the second characterisitc, Accuracy, etc.

For each characteristic enter all names in the appropriate space. Assign the ratings as closely as possible in accordance with the percentages indicated.

	Lowest 10%	Next lowest 25%	Middle 35%	Next highest 25%	Highest 10%
Amount of Output					
Accuracy					
Punctuality					
Initiative					
Cooperativeness					

FIGURE 12.6. *Part of a form using group-order rankings.*

Another type of scale is the adjective or category scale, such as the following:

Ability to work smoothly with others:

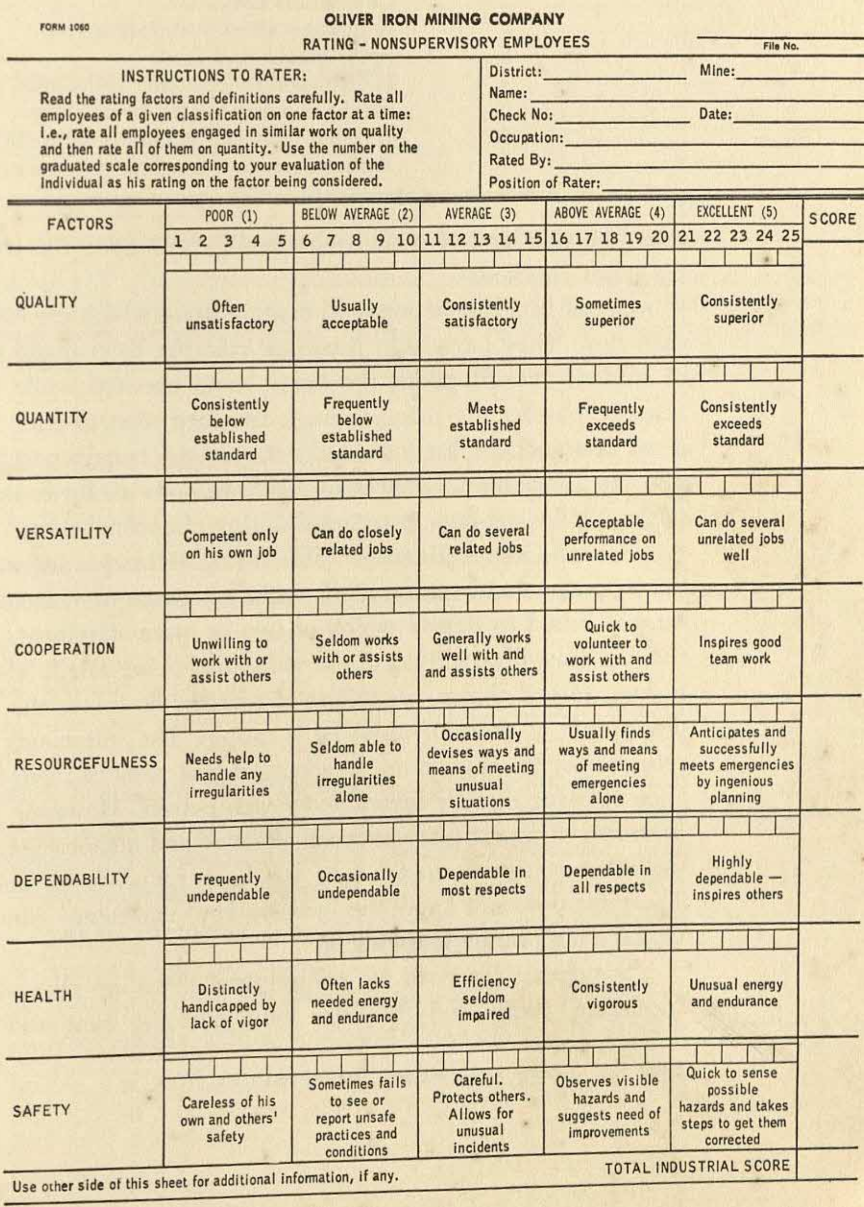
Has frequent difficulties in working relationship with other people	Somewhat ineffective in getting along with co-workers	Usually effective in giving and obtaining cooperation	Nearly always maintains friendly working relationships

Frequently, a combination of the numerical and category scales are used. An example of a form similar to many in use in industry is presented in Figure 12.7.

Generally speaking, rating scales have been most successful and reliable when they have provided the most exact definition of the behavior to be rated and the scale to be used. Studies have also demonstrated the importance of training the raters in the use of such scales, particularly in the avoidance of errors of judgment previously described. While halo effect and constant errors are present in these scales, they can be minimized by suitable training of raters.

Check Lists. A modification of the rating scale, the *check list*, is designed to have the rater make a simple judgment that certain statements either do or do not describe the worker's actual job behavior. By this means, the attempt is made to avoid many of the errors in judgment which are common in ratings. In a check list, the supervisor is not asked to rate a

Figure 12.7. *A merit-rating form used in a large company. The form combines numerical and category scales. (From Dooher, M. J., and Marquis, V. (Eds.),* Rating employee and supervisory performance. *New York: American Management Association, 1950)*



FORM 1060

OLIVER IRON MINING COMPANY

RATING - NONSUPERVISORY EMPLOYEES

File No.

INSTRUCTIONS TO RATER:

Read the rating factors and definitions carefully. Rate all employees of a given classification on one factor at a time: i.e., rate all employees engaged in similar work on quality and then rate all of them on quantity. Use the number on the graduated scale corresponding to your evaluation of the individual as his rating on the factor being considered.

District: Mine:
Name:
Check No: Date:
Occupation:
Rated By:
Position of Rater:

FACTORS	POOR (1)	BELOW AVERAGE (2)	AVERAGE (3)	ABOVE AVERAGE (4)	EXCELLENT (5)	SCORE
	1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	
QUALITY	Often unsatisfactory	Usually acceptable	Consistently satisfactory	Sometimes superior	Consistently superior	
QUANTITY	Consistently below established standard	Frequently below established standard	Meets established standard	Frequently exceeds standard	Consistently exceeds standard	
VERSATILITY	Competent only on his own job	Can do closely related jobs	Can do several related jobs	Acceptable performance on unrelated jobs	Can do several unrelated jobs well	
COOPERATION	Unwilling to work with or assist others	Seldom works with or assists others	Generally works well with and and assists others	Quick to volunteer to work with and assist others	Inspires good team work	
RESOURCEFULNESS	Needs help to handle any irregularities	Seldom able to handle irregularities alone	Occasionally devises ways and means of meeting unusual situations	Usually finds ways and means of meeting emergencies alone	Anticipates and successfully meets emergencies by ingenious planning	
DEPENDABILITY	Frequently undependable	Occasionally undependable	Dependable in most respects	Dependable in all respects	Highly dependable — inspires others	
HEALTH	Distinctly handicapped by lack of vigor	Often lacks needed energy and endurance	Efficiency seldom impaired	Consistently vigorous	Unusual energy and endurance	
SAFETY	Careless of his own and others' safety	Sometimes fails to see or report unsafe practices and conditions	Careful. Protects others. Allows for unusual incidents	Observes visible hazards and suggests need of improvements	Quick to sense possible hazards and takes steps to get them corrected	
					TOTAL INDUSTRIAL SCORE	

Use other side of this sheet for additional information, if any.

trait like "dependability"; instead, he is required to check whether he has observed certain specific instances of dependability, as reflected in an item such as, "He is consistently on time with his reports–." Another panel of "expert" judges has previously evaluated such items in terms of their importance to success on the job in question. An example of a set of items for the job of short-order cook is given in Table 12.5, along with their relative weightings as they might be judged by such a panel. An individual's rating on this kind of scale is obtained by averaging the weighted value of the items checked.

TABLE 12.5

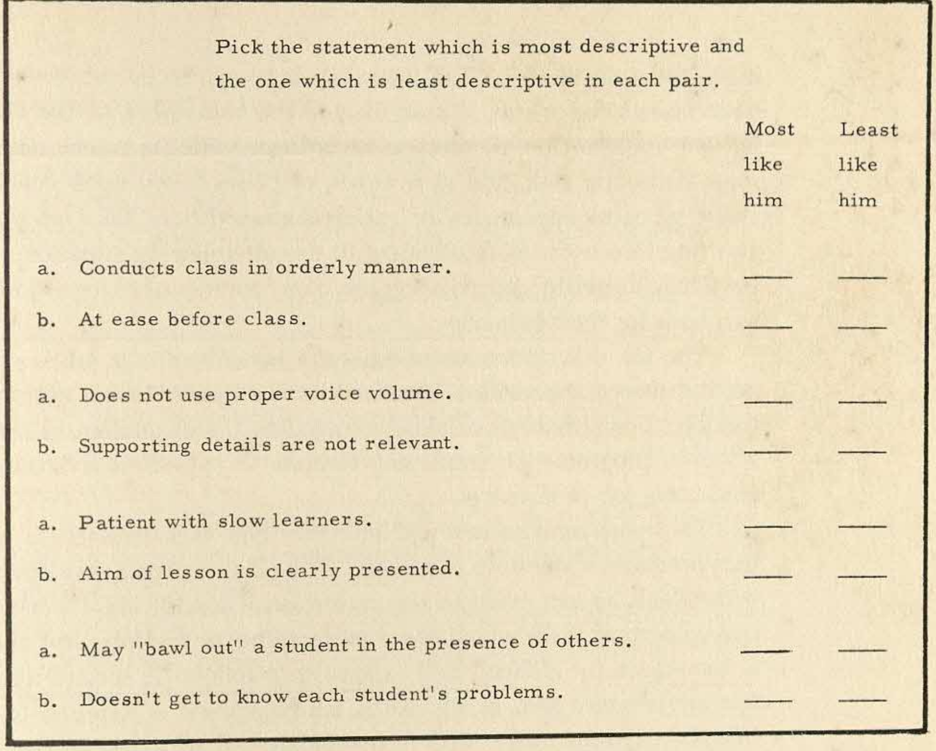
STATEMENTS OF OBSERVED BEHAVIOR APPLICABLE TO THE JOB OF SHORT-ORDER COOK, AND THEIR WEIGHTINGS FOR JOB SUCCESS

Weighting	*Statement of Behavior*
1	Gets orders confused.
2	Requires waiters to repeat orders.
3	Spills grease and food.
4	Is disturbed by customer comments.
5	Arranges orders neatly for delivery.
6	Handles tools and materials methodically.
7	Remembers several orders in sequence.

Check lists can be made to contain items which are even more specific than this. They have been used, for example, to evaluate the performance of student aircraft pilots, the items being checked while the student was actually putting the plane through specified maneuvers.[2] In this case, the items of the check list indicated not only the behavior to be observed, but also the allowable tolerances in this behavior (as, for example, a tolerance of ± 30 miles per hour in airspeed during a specified turn).

FORCED-CHOICE RATINGS. This rating technique attempts to eliminate the halo effect and certain other errors by a somewhat novel approach. The rater is asked to decide which of two or more statements is most descriptive (or least descriptive) of the individual being rated. He must, however, make a *forced* choice, regardless of whether he thinks the statements to be descriptive of the individual he is rating. The statements from which the rater makes his choices are so arranged that pairs of them have the appearance of being equally favorable to each person. However, one of each pair is known to discriminate between effective and ineffective individuals, while the other statement in the pair has been found to be non-discriminating. The rater does not know the "scoring key" and hence cannot give an individual a high rating intentionally.

Sometimes the pairs of "undesirable" items are presented with pairs of "desirable" items, and the rater must pick the most and least applicable



Pick the statement which is most descriptive and the one which is least descriptive in each pair.

	Most like him	Least like him
a. Conducts class in orderly manner.	____	____
b. At ease before class.	____	____
a. Does not use proper voice volume.	____	____
b. Supporting details are not relevant.	____	____
a. Patient with slow learners.	____	____
b. Aim of lesson is clearly presented.	____	____
a. May "bawl out" a student in the presence of others.	____	____
b. Doesn't get to know each student's problems.	____	____

FIGURE 12.8. *Items used in a "forced-choice" performance rating form for technical school instructors. (From Highland, R. W., and Berkshire, J. R.,* A methodological study of forced-choice performance rating. *Lackland Air Force Base, Texas: Human Resources Research Center, Research Bulletin 51-9, May 1951)*

from each set of four items. Figure 12.8 gives some examples of these items used in a form to evaluate training instructors. It is certainly not possible for the rater to determine which are the best items to check; he must stick to the observable behavior. This technique has been found to be an effective one in a number of situations, although sometimes raters do not like to use it.

SUMMARY

The application blank and the employment interview are frequently used in combination for personnel selection. The former contains questions about the past history and personal life of the individual applicant. Such items often reflect also *motivation* and *interest* factors which correlate with job success. The items on the blank may be *weighted* in accordance with their validity to determine a score used in selection.

The interview is widely used for selection of personnel, although in general it does not have a high degree of demonstrated validity in predicting success on the job. The interview is known to be subject to errors in interviewer's judgments. These include the *halo effect,* or the tendency to rate an applicant on all traits in accordance with the rater's impression of some particular trait, and *stereotypes,* or biases based upon general beliefs about physical appearance or racial characteristics. *Lack of rapport* can also interfere with good judgment in the interviewing situation. Generally speaking, successful interviewers use many sources of objective information as a basis for their estimates.

The job description states what the incumbent of a job is expected to do, but does not provide a standard for the *quality* of his performance on the job. For a number of reasons including the evaluation of training and selection programs, an employing company or plant must interest itself in *evaluating job proficiency.*

The most fundamental and objective type of assessment is one which uses *production measures or records.* The plant manager may devise records with which he can evaluate the performance of individual workers on certain important tasks which are representative of the job. But this method is sometimes too difficult and expensive to follow. A second alternative is the *performance test,* in which the job incumbent is required to carry out selected, representative tasks in a standardized situation, so that an *objective score* can be assigned to his performance.

Another method of proficiency assessment is the *job-knowledge test.* Such tests are designed to measure the possession of essential job knowledge (usually, identification, sequences, and concepts) as they have been identified by the job analyst. Job-knowledge tests are highly useful and easy to administer and score. The relationship (degree of correlation) of knowledge to performance, however, needs to be demonstrated in each case, in order that *validity* be established.

Finally, another widely used method of assessment is rating, which may be done by *ranking* individuals, or by using *rating scales.* Where relatively few individuals are involved, ranking in terms of defined performances is an adequate procedure. Rating scales are particularly useful when comparisons of larger numbers of individual employees are desired. Rating methods involve difficulties which depend upon the subjectivity of rater's judgments, and which include *constant errors,* the *halo effect,* and *personal biases.* Generally, these may be partly overcome by training the raters and by using well-defined categories of human activity to which the judgments apply. Other types of rating methods which attempt to minimize judgment errors are *check lists* and *forced-choice* ratings.

READING REFERENCES

Anastasi, A., *Psychological testing.* New York: Macmillan, 1957. A textbook describing principles of test development and test usage and a survey of specific tests in the areas of ability and personality measurement.

Bellows, R. M., and Estep, F. M., *Employment psychology: the interview.* New York: Rinehart, 1957. A textbook on the role of the employment interview and allied techniques of personnel selection.

Ghiselli, E. E., and Brown, C. W., *Personnel and industrial psychology* (2nd Ed.). New York: McGraw-Hill, 1955. A textbook containing chapters on job analysis, selection procedures, the measurement of proficiency, and rating methods.

Shartle, C. L., *Occupational information* (2nd Ed.). New York: Prentice-Hall, 1952. A description of occupational information and job analysis, and their uses in placement.

Tiffin, J., and McCormick, E. J., *Industrial psychology* (4th Ed.). New York: Prentice-Hall, 1958. A textbook with major emphasis on job analysis, testing, and proficiency measurement.

U. S. Dept. of Labor. *Dictionary of occupational titles,* Vols. 1 and 2. Washington, D. C.: U. S. Govt. Printing Office, 1939. The fundamental reference on occupations, providing categories of occupations and brief descriptions of thousands of job categories.

13

TRAINING

Once people have been selected for jobs, they very often have to be trained. The purpose of training is to have people learn the specific skills they need to carry out effectively the performances required in the job. Designing a training program is a matter which draws heavily upon the principles of learning described in Chapter 6, and referred to in subsequent chapters. Here we tell how these principles are put to use in various kinds of training programs. You will be able to see how learning can be used to improve the performance of human beings in a variety of industrial and military situations.

Perhaps the most common technique employed by society to influence human behavior is training. Through one kind of training or another, the individual acquires the basic abilities he needs to exist in our society, the knowledge and skills he uses for play and work, and his attitudes and beliefs toward other individuals and the world he lives in. Most of the characteristics of the adult human being are the result of training, whether it has been formally organized or not. Deprived of training, the human being would develop as a strange creature indeed.

Training is defined as the set of conditions employed to increase the level of performance of some human function by means of learning. Thus, a regimen of physical exercise to increase the strength or girth of muscles is not training, as we define it here, because learning is not involved. But reading a book, on the other hand, *is* training, provided it can be shown that something has been learned from it. Sometimes, it is true, training is instituted to establish some "new" skill; this simply means that the level of performance started from zero. More typically, the increase in performance is from some measurable point. Thus, training of the school child in the rules of multiplication often starts with knowledge of the rules about two times two.

The arrangement of conditions to induce learning may be more or less deliberate, more or less well organized. Parents train children in the elementary skills of manipulating, locomotion, communicating, dining, and elimination in relatively unorganized ways (although they may be guided by books on child-rearing). Schools introduce a high degree of organization into the process of training, with emphasis first on the fundamental rules of concept-using, and later on the acquisition of organized conceptual knowledge. Trade schools and programs of industrial and business training are other examples of organized efforts to produce learning of specific skills. Throughout his life, the individual is exposed to various forms of training by his exposure to newspapers, television, radio, and motion pictures. This training is primarily designed to establish new concepts (rules, attitudes) and to raise the level of strength of old ones.

In conformity with the aims of this book, we shall consider in this chapter the process of training as it applies to human work. This means a concern with the types of training that may be used to improve the performance of individuals in jobs. We shall rely, mainly, on examples drawn from training programs which might be used in industrial, business, government, or military organizations. Analogies with other, more broadly conceived training programs such as those of schools and churches are often appropriate, as the student will recognize.

Selection and Training

In the previous chapters we discussed the topics of job description and personnel selection. As we noted, it is a rare organization that can fill its skill requirements merely by selecting appropriately trained individuals from the manpower resources of the community. Generally, some combination of selection and training is necessary. No matter how carefully men have been selected, some kind of training is essential if they are to reach satisfactory levels of performance on specific jobs. In some instances, emphasis must be placed on training rather than selection. This happens, for example, when there is a manpower shortage in a particular area or when only low-ability people are available. When there is a full pool of manpower from which to select, tests and other procedures may be useful in selecting those individuals most likely to profit from the training.

The Specificity of Training

A distinction is often made between education and training. "Training" usually refers to the teaching of specific skills. It is oriented toward a job, as when we speak of "pilot training" or "lathe-operator training."

Education usually refers to teaching with a broader objective. The purpose of education is to develop more general abilities and knowledge which can provide a basis for learning many specific skills at a later time. The most basic example of this is our elementary education which attempts to provide everyone with a common repertoire of verbal, conceptual, and numerical abilities. The subjects taught in high school and college are not so general, but they are likely to transfer to several jobs or occupational fields as well as to nonvocational activities.

The designer of a training program is often faced with the issue of specificity of training versus breadth. Specific training gets people on the job and to a high level of skill faster. More general training may make an individual more adaptable to a variety of jobs, to changes in a job, or to new situations or procedures. At one extreme, we have one major company which sends its executives to a university liberal arts program for a year. No management courses are taught, but the assumption is made that general abilities and concepts are being developed which underlie an objective viewpoint and which will transfer to decisions on the job. Most programs are at the other extreme, where an individual is trained, for example, to operate a specific punch press or to sell a certain product. Some training programs are a compromise between these objectives; they include training in specific skills as well as in abilities that can be generalized.

Training Objectives and Methods

A first step in setting up a training program is to determine objectives. It is not enough to state that the program is to produce a good salesman or a proficient radar operator. The objectives need to be stated in terms of the particular knowledge, skills, and attitudes that are to be acquired, as well as the performances to which they apply. The basic tool for defining what must be learned is the systematic job and task analysis described in Chapter 11.

In this chapter we shall describe a number of training methods. It is important to emphasize at the outset that the method which is best for one objective may be completely inadequate for another. The value of a particular method can be evaluated only in terms of what is learned by the trainee. Thus, the technique of role-playing, which we will discuss later, may be quite effective in management training but relatively ineffective in teaching procedures. Training films may be effective in teaching mechanical operations, but not so successful in changing attitudes. On-the-job training may work well for certain industrial machine operations, but it has serious drawbacks in training passenger-plane pilots.

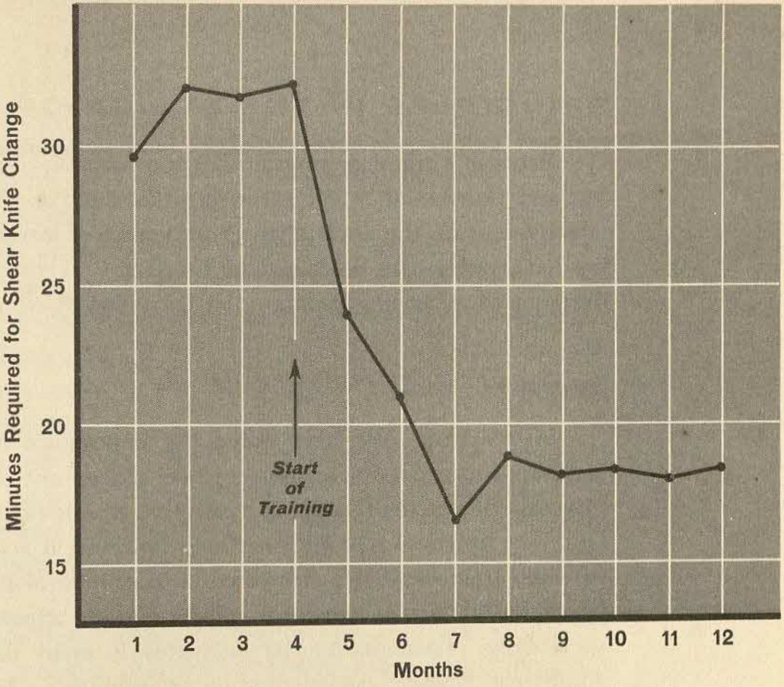


FIGURE 13.1. *Effect of a training program on the job performance of individuals who had been on the job more than a year. The curve shows a drop in time required to change knives in a flying shears.* (After Greenly, R. J., *Job training,* National Association of Manufacturers Labor Relations Bulletin, No. 35, *1941*)

Training and Experience

A good deal of training is done with individuals who have been on the job for some time. One might suppose that such individuals have already picked up the required skills from experience, or at least that they are operating at their own optimum level. But hundreds of examples show that this is not always so. Training of workers who have been on the job for years can achieve remarkable changes in behavior. Figure 13.1 gives one example of this for the operation of changing knives on a flying shears. Employees had been on the job for more than a year prior to the new training program. The average time for the operation prior to training was about 30 minutes. Following the training, the drop in time continued for three successive months, at the end of which time the operation took 18 minutes. The saving to the company by this one training program was calculated at $1,740 per month or $20,880 per year. From this instance, it is apparent that unguided experience may lead to the learning of inefficient skills as well as efficient ones. Experience is not necessarily the *best* teacher in all situations.

PRINCIPLES IN THE DESIGN OF TRAINING

Because a training program has the function of making possible learning and transfer, it is not surprising that such a program depends for its effectiveness on the application of principles of learning and transfer which we have previously described in Chapter 6. From the standpoint of the designer of a training program, let us review these principles briefly here.

Learning

MOTIVATION. We have noted the importance of having a motivated individual in order for learning to take place most efficiently. In a laboratory experiment, motivation is a variable that is relatively easy to manipulate. For practical training situations, however, it is often not easy to motivate the trainees. Since this essential condition of human learning cannot be neglected in a successful training program, attention must be paid to it specifically. Trainees may be motivated in many different ways. For example, the training period may be preceded by a lecture or movie which explains the purpose and the benefits of training to the individual in terms of increased skill, increased value of the employee to the company, increased earning potential, etc. Another commonly employed motivating device may be the award of a diploma or certificate signifying successful completion of the training course. In some instances, direct increases in pay or other monetary rewards may be employed.

The important thing is that trainees see these or other incentives in relation to their own needs. In other words, they must see the training as a goal that results in further advancement, job security, satisfaction, or increased pay. On the other hand, if a new work method is seen as a threat to an employee's security, training in this method is not likely to be effective even if an increase in pay is involved. Similarly, training in "human relations" for supervisors may be seen by trainees as a method for "manipulating" people more easily. If this happens the behavior resulting from the training is likely to be different from what is intended.

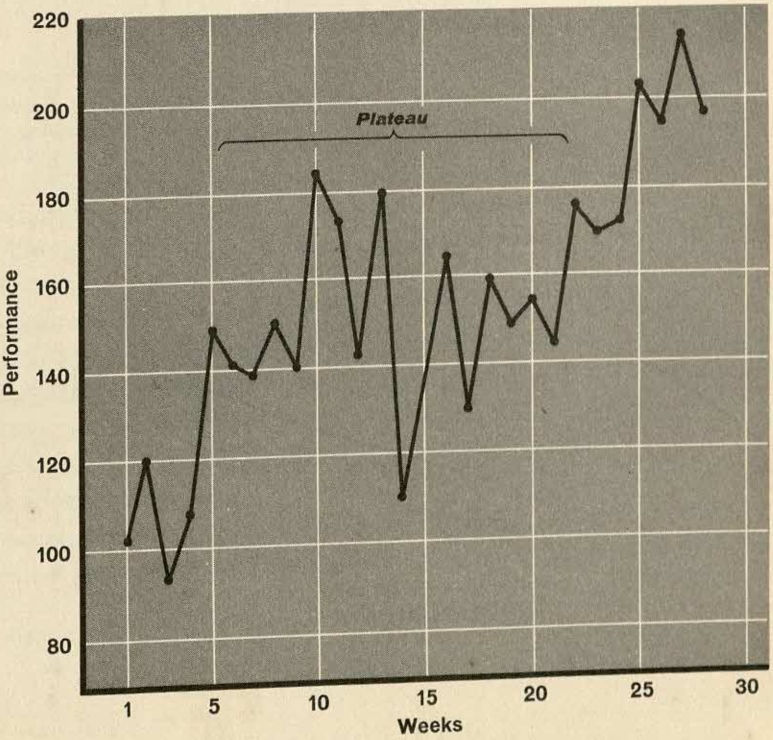
Setting realistic goals is an important aspect of motivation in training. As we saw in Chapter 4, a marked discrepancy between the individual's *level of aspiration* and his achievement may have an adverse affect on the success of training.

FREEDOM FROM DISTRACTIONS. We have noted that learning requires freedom from emotion-producing distractions. This principle, too, is of importance to a successful training program. Sometimes, it means that the provision of a special environment for training (such as a separate room for practice) can greatly increase training efficiency by removing it from the emotional "pressures" of the actual job situation. Or, the principle may mean that fellow workers must be instructed not to introduce unwanted distractions by their tendency to heckle the trainee during practice. Trainees may have different degrees of anxiety about the training and their performance in it. A certain amount of anxiety has been shown to facilitate learning, but if the anxiety is intense it may interfere with learning.

PRACTICE. The training program should provide opportunity for the practice of the skills, models, concepts, or whatever is being learned. As we have seen previously, learning does not occur without at least a minimal amount of practice, so far as we know. One thing to be avoided in a training program is the acquisition of "sheer" verbal habits and sequences when this is not what is wanted. Lecture methods and motion pictures sometimes permit the trainee to learn to "talk a good job" without being able to put this verbal knowledge into practice. One main reason for providing practice situations is to insure that what is learned is what is required by the job.

The amount of practice that is best depends on the kind of task, the level of ability of the trainees, and the procedure used. Sometimes time limits are arbitrarily set without information on the amount of practice needed, as indicated by a final "leveling off" of a learning curve. The at-

FIGURE 13.2. *Learning curve for new taxicab drivers. (After Ghiselli, E. E., and Brown, C. W.,* Personnel and industrial psychology. *New York: McGraw-Hill, 1955)*



tainment of a level stage of performance, however, may be only an intermediate *plateau*, and this may be precisely the stage where training in new work methods or additional incentives are needed. Figure 13.2 shows the learning curve for a group of new taxicab drivers. Had the training been brought to a halt after the seventh week, it might have been assumed that a final level had been reached at that point. But this performance would have been approximately 50 percent less than what the drivers were capable of doing.

The *schedule* of practice is also important. In most cases, if a given amount of practice is allowed, spaced practice is better. Table 13.1 provides a demonstration of the effects of spaced practice in the gunnery training of pilots. Each pilot was given 2,000 rounds to fire at a towed target. Some pilots fired these rounds in 4 missions, others took as much as eight. The performance of pilots with 8 missions was more than five times better than those who finished in four.

TABLE 13.1
THE RELATION BETWEEN DISTRIBUTION OF PRACTICE AND FINAL PROFICIENCY IN AERIAL GUNNERY FOR 221 FIGHTER PILOTS

Number of missions taken to shoot 2,000 rounds	*Number of pilots*	*% of hits on target on last mission*
8	28	5.3
7	31	3.8
6	85	3.0
5	59	1.9
4	18	1.0

(Data from Crawford, M. P., *et al.*, *Psychological research on operational training in the Continental Air Forces.* AAF Aviation Psychology Program *Research Report No. 16*, Washington; Government Printing Office, 1947, p. 261.)

REINFORCEMENT. Many practical training studies attest to the value of the principle of learning which states that reinforcement must be provided as soon as possible after the occurrence of each practice trial. Usually, reinforcement takes the form of knowledge of results fed back to the trainee; that is, the learner is told the degree of correctness of his responses. The designer of a training program attempts to arrange the conditions of learning so that feedback will be as immediate as possible. Waiting until the end of a training session is not likely to be very effective. In the case of a motor skill like hammering nails, arranging reinforcement may be inherent in the practice situation. The learner knows immediately whether he has hit the nail or not. In other instances, such as the establishment of successful sales techniques and skills, immediate reinforcement may require a fairly elaborate procedure. But its effectiveness is none the less evident when correctly applied.

The design of training must take into account other types of reinforcement besides direct knowledge of results. For example, banks would like their tellers to be cheerful to customers and also to be accurate in their accounts. Yet the behavior that is reinforced during the training period is likely to be almost exclusively the latter. As a consequence, the teller on his job is likely to be preoccupied with his accounts, rather than with personal attention to customers. Similarly, universities would like professors to excel in teaching as well as research. Yet it is frequently true that the behavior which is rewarded during training as well as on the job is the performance and publication of research. In an industrial program when speed was inadvertently rewarded more than accuracy, the result was undesirable waste on the job. Clearly, the reinforcement pattern needs to be designed to establish the total pattern of behavior desired for the job.

Transfer of Training

Principles of transfer of training are of great significance to formal training programs. The designer of a training program is concerned with measuring the amount of transfer trainees are likely to exhibit to the new job. If trainees come from other jobs in the plant, and adequate job descriptions are available, it may be possible to estimate the amount of transfer to be expected between jobs. But the main reason for concern with transfer is that it provides the criterion of effectiveness of training in terms of job performance.

AMOUNT OF LEARNING. We have seen in Chapter 6 that the amount of transfer increases with the degree of initial learning. The designer of a training program is of course interested in this very important principle. Practically, it means that he should not expect to be able to demonstrate important amounts of transfer to job performance, unless he knows (that is, has previously demonstrated) that there has been considerable learning. In order to determine, for example, whether a lecture on "road courtesy" has brought about transfer in cutting down driver accidents, provision should be made to find out first whether the lecture itself produced learning. Otherwise, any gains which have been noted may be attributable to other factors (such as, for example, improvement in motivation).

The procedure of *overlearning* may be especially important in some kinds of training. This is particularly true when certain critical aspects of skill are not likely to be practiced often on the job. Thus, an interceptor pilot is given training in a simulator (compare Figure 13.14) in tracking enemy targets. While he may not practice this much on the job, it is critical that he keep this skill at a high level. Continued practice in training well beyond the point where improvement is measurable may facilitate retention of this skill and its transfer to the job.

SIMILARITY OF TRAINING AND JOB SITUATIONS. A most important factor in the effort to insure transfer to the job from training situations is that of similarity. As we saw in Chapter 6, the amount of positive transfer increases with the degree of similarity between the learning and transfer tasks. This means that the designer of training must pay close attention to the representation of the desired performance within the training situation. Training should be made as "realistic" as possible, to meet this condition. This does not mean that one must always carry the job and its associated equipment intact into the training situation; from the standpoint of learning, this may be an unduly costly and even inefficient thing to do. But the training situation must nevertheless resemble the job, particularly in its stimulus aspects, in order for transfer to be highest. A serious mistake is sometimes made in substituting verbal stimuli (words), during training, for real objects or at least pictures of them. Transfer may be quite low in such circumstances. This is what is meant by saying that a given example of training is "too abstract" or "too theoretical." This point is related to our previous discussion of *practice*.

Another principle falling under the general heading of similarity is the *variety* of situations that should be represented. Training should resemble the job in the variety of stimulus situations provided. A basketball coach would not think of depending on training which concentrated solely on shooting baskets; he takes care to insure that all possible game situations are represented in training. Likewise, as modern armies know, training in target-shooting provides highly inadequate representation of the variety of rifle-using situations carried out in infantry combat.

Evaluation of Training Effectiveness

The determination of effectiveness of any training program is also a matter of measuring the amount of transfer from training situation to job situation. The evaluation of training must sooner or later come down to the question of the degree to which training has accomplished its stated purpose. In gauging the effectiveness of a training program, measures of opinion seldom tell the true story. The opinions of trainees and instructors, although sincere, may be misleading. For example, supervisor trainees in "human relations" training programs almost universally have the opinion that such instruction is more effective than, in fact, it turns out to be when assessed as amount of transfer to supervisory performance.[1]

As we pointed out in the previous chapter, the evaluation of training requires a *standard* (or *criterion*) of successful job performance. Training objectives need to be derived directly from such a criterion. Thus, a training program may be instituted for the objective of increased production, decreased waste or breakage, improved quality of product, reduction in absenteeism, or improved supervision. The criterion which defines objectives is also used as the standard for transfer of training. For example, if supervisory training has been given, a good measure of effectiveness would be provided by changes in the attitudes and performance of individuals who work under the supervisors, before and after the latter's training. The method described in Chapter 6 to study transfer of training can be generally used to evaluate training effectiveness.

TRAINING MEDIA

Having seen what general principles of learning and transfer are available for application to the design of training, we need now to consider the kinds of situations which may be set up to permit learning and transfer to occur. From this point of view, training situations can be most conveniently classified according to the *medium* used for learning. Although such media do not in themselves fully account for the conditions of learning, they do provide the distinctive features of practical training situations.

The major media for training may be thought of in four major classes. First, there are *verbal media,* which depend upon printed or spoken communication of words, as in books and lectures. Second, there are *audio-visual media,* which display pictures and picture sequences to the learner, often accompanied by verbal remarks, as in motion pictures and television presentations. Third, there are *training devices,* which permit the trainee to practice certain specific abilities required by the job. Finally, training is frequently conducted in the *job situation* itself. We shall discuss each of these in turn, giving some account of their differential features, the kinds of human abilities to which they are applicable, and some evidence which serves to illustrate their effectiveness in each case.

VERBAL MEDIA: LECTURES AND BOOKS

A lecture situation is one in which a speaker orally delivers an organized set of conceptual material to a group of trainees. The lecturer may depend to some extent on visual presentation. That is, he often depends upon blackboard materials, charts, slides, or even motion picture sequences.

The distinguishing feature of the lecture, however, is that its basic conceptual organization is contained in the words of a speaker.

An instructional lecture is best designed to convey the kind of material that can be acquired by a class of trainees in a small number of practice trials. This means that the lecture has a high probability of being a successful medium for training certain kinds of human performances, but is unlikely to be successful for others. Since it is a medium that is attractive because inexpensive, there is often a temptation to use the lecture for quite inappropriate purposes. Therefore it will be desirable for us to distinguish the kinds of performances the lecture can train well from those it cannot.

A book or training manual is like a lecture in that it presents verbal material, in this case, printed. Such material is also usually interspersed with illustrations and diagrams, although it is basically conceptual in character. Of course, printed material is much more versatile than is a lecture, since the reader may repeat the reading of passages he has not learned, as many times as he wishes. For this reason, a book does not necessarily depend on single-trial presentation of its material. Undoubtedly, though, training manuals are often read only once.

Concept Learning

Both lectures and printed materials are often used successfully to produce learning of *concepts*. As we have seen previously, human beings are often able to acquire concepts in a single trial, probably by means of transfer of training from more general concepts. Verbal media are often used to *define classes* of objects. This is what is accomplished in an orientation lecture or a booklet, designed to acquaint a new employee with the plant where he is to work, for example. Such a presentation might distinguish the various parts of the plant and the operations located in these parts. If these classes of things are not too numerous, the employee may be able to acquire them on the basis of a single lecture or a single reading.

Rules are another kind of concept often learned through verbal media. Rules of the road may be given to a class of driver trainees in a lecture; or rules of safety in a factory department may be similarly presented. Of course, the limitation of number of rules which can be mastered in a single lecture must always be considered. If the rules are many, there may be interference between the sets of verbal responses induced in the learner, and the single lecture will to this extent be ineffective. A training manual, on the other hand, may be used by the learner in such a way as to reduce interference in learning, if he sets out to learn only a few rules at a time.

The lecture is widely used in attempts to establish general concepts called *attitudes*. A company may use lectures to new employees, for example, to establish favorable attitudes toward their new work or the company's product. The armed services may use lectures during wartime to establish in their members particular attitudes toward the nature of the conflict and toward the enemy. The lecture was widely used for this purpose during World War II. In general, it has been demonstrated that the lecture may change attitudes which have been recently acquired, or those that do not control strong emotional reactions.

An interesting illustration of the effectiveness of the lecture as a medium for establishing attitudes occurs in an Army study with basic trainees. This particular study compared the effectiveness of a "canned" lecture, or commentator transcription, with a transcribed dramatic program designed to make the same change in attitude. The content of both these programs was intended to counteract attitudes of overoptimism about a quick end of the war in the Pacific. Generally speaking, the transcriptions contained factual material concerning the status of the war effort, United States and enemy capabilities. The lecture-type transcription was made to resemble a radio news-commentator program, while the dramatic presentation employed actors and background music to dramatize the underlying events. The study employed a control group which heard neither presentation, a group which heard the commentator programs, and a third group which heard the dramatic programs. These groups were comparable with respect to general intelligence, age, education, and region of birth. The attitudes of each group were sampled by means of a questionnaire, before and after hearing the transcriptions. The results of this study are summarized in Table 13.2.

TABLE 13.2
PROPORTION OF MEN WHO REVISED ESTIMATE OF PROBABLE LENGTH OF WAR WITH JAPAN AFTER GERMANY'S DEFEAT (REVISION—AT LEAST ONE-HALF YEAR)

	No program (control group) (*N*=181)	*Commentator programs* (*N*=401)	*Dramatic programs* (*N*=179)
No change	63%	45%	42%
Revised estimate *upward*	18	47	50
Revised estimate *downward*	19	8	8
Net percent revising upward: (Percent revising upward minus percent revising downward)	−1%	39%	42%

(From Hovland, C. I., Lumsdaine, A. A., & Sheffield, F. D. *Studies in social psychology in World War II, Volume III: Experiments on mass communication.* Princeton, N. J.: Princeton University Press, 1949.)

As the table shows, the number of people in the control group showing a change in attitude when questioned on the two occasions was not significant. For those who heard the programs, however, around 40 percent revised upward their estimate of the probable length of the war with Japan. The lecture was about as effective as the more elaborate and expensive dramatic program in bringing about a change in attitude. Other studies have shown that lectures may have a greater effect on attitude change than do equivalent materials presented in printed form.[2]

Some Limitations of Verbal Media

The single-trial characteristic of lectures limits their usefulness in establishing the *sequences* involved in procedures. If the sequence is short, it can of course be mastered in one trial. If long, we know that interference among the terms will occur, and must be overcome by additional learning trials. Thus, if setting up a machine for operation requires only the two steps of "Set lever in off position; turn on power switch," this sequence may be adequately acquired from a lecture. But if the setting-up process requires five steps, or ten steps, or twenty steps, obviously the lecture will be decreasingly effective as a medium for learning.

For some kinds of abilities, verbal media fail to provide the proper stimuli, and therefore cannot be used effectively for learning. This is true of the learning of models and scales, and also the learning of motor skills. As we have seen, the learning of identifications through models and scales depends on the presence of stimuli which arise directly from physical changes in the environment. We cannot learn to identify colors, sizes, shapes, or tones, unless these kinds of stimuli are present in the learning situation. Similarly, the learning of motor skills typically requires the presence of both environmental stimuli and kinesthetic stimuli from the muscles. The lecture can name these stimuli, but it can never convey them directly to the learner. Each of us has probably experienced this lack of effectiveness at one time or another. Perhaps there has been an occasion when we noted, with impatience, how impossible it is to train someone to perform a particular motor act (like tying a tie) by "telling him how" in words. The formal presentation of words in a lecture has no greater likelihood of success in training motor skills.

We mentioned earlier that the lecture has limitations in changing certain kinds of intense attitudes. This fact was described in an earlier chapter, in connection with studies of housewives' attitudes toward certain meats, of baby feeding habits, and of workers' attitudes toward new work methods. Similarly, lectures are not particularly effective in teaching skill in human relations to supervisors, although a temporary attitude change may result "at the verbal level." For changes in these kinds of attitudes, methods which make use of group participation and social pressure are more effective, as we have already seen. Changing attitudes which are deeply ingrained may require therapeutic or prolonged techniques. Other techniques besides the lecture method were used by the Chinese Communists in their "brainwashing" of American soldiers.

AUDIO-VISUAL MEDIA

Audio-visual presentations take many forms, and we shall not be concerned here with a complete account of all these forms. The visual part of the presentation is made possible by the photographic camera and the processes of film development, printing, and projection; and also by the television camera and electronic devices which transform light waves into impulses and back again into an image on the television screen. The auditory portion of such presentations may consist of reproduced recordings of the actual sounds in the scene being photographed, or it may be added later in the form of a running commentary or synchronized lecture. The two most widely used forms of audio-visual presentation are motion pictures and television.

In terms of its versatility as a training medium, the motion picture has one inherent advantage over "live" television. This is the fact that the camera produces a permanent visual record on film, which can then be readily cut and arranged in any sequence desired. The artistry of motion pictures is fundamentally dependent on the opportunity photographic film provides for the arrangement, cutting, and intercutting of sequences of recorded events. This same characteristic may provide opportunities for effective training which have by no means been fully exploited as yet.

As a training medium in its simplest form, the motion picture or television presentation may be nothing more than a recorded lecture. There are practical advantages to such recording, of course. By means of it, a single lecture may be made to reach a large number of separate classes of trainees, either simultaneously or during successive periods. Furthermore, when used in this way, it is possible to search out the best possible lecturer, the one who is known to be most effective in "getting his material across," rather than depending on several different lecturers of varying ability. But these advantages do not arise from any inherent properties of audio-visual presentation. A lecture presented on film or television is still a lecture, and there is nothing magical which will make it acquire additional training value simply because it is seen on a screen and heard as sound waves emanating from electromagnetic speakers. The training possibilities and limitations of this form of lecture are exactly those we have described in the previous section.

Unique Characteristics of Motion Pictures

Certain features of motion picture presentation do, however, provide unique conditions for learning. Let us consider what these are.

REPRESENTING DYNAMIC EVENTS. Movies can directly represent to the viewer models which involve motion or change in time. For example, the identification of the spot on a runway being approached during a landing glide apparently depends on the acquisition of a dynamic model of this sort. The static pictures shown in Figure 13.3 illustrate the kind of changes on which such a model depends. Concepts which partake of motion or sequences of events in time can also be well represented in motion pictures. An example might be the rule governing the sequence of events taking place in the firing of an explosive mixture in the cylinder of an automobile motor. Although such a rule can be expressed verbally in a series of steps, the dynamic nature of the concepts of valve motion, cylinder motion, and spark occurrence can be well presented in movies. In connection with this particular feature of motion pictures, it may also be emphasized that the versatility of dynamic representation is enormously increased by the use of animation and special effects. The learner can see through solids; he can see things more slowly than they actually happen. These and many other techniques are available peculiarly to motion pictures as a training medium.

REPRESENTING THE CONSEQUENCES OF ACTION. Motion pictures can represent to the learner the consequences of right and wrong actions. This feature is important because of its relation to the principle of reinforcement. The trainee, for example, is able to see and vicariously experience the results of an error or mistaken judgment. No one would be inclined to permit a student of automobile driving, for example, to experience many of the consequences of incorrect judgment directly. But a motion picture can accomplish much the same effects of reinforcement by permitting him to see them on a screen. Similarly, the trainee is able to experience the consequences of correct action: to see an action well executed or a problem correctly solved.

THE POINT OF VIEW OF THE LEARNER. One of the most interesting characteristics of the motion picture, from the standpoint of its training potential, is its ability to show a situation or task from the point of view of the learner. The observer thus feels himself a part of the action being shown on the screen, rather than an outside observer. The dramatic effectiveness of the "subjective camera" has been known and used in entertainment movies for many years. Its motivating value in training may also be

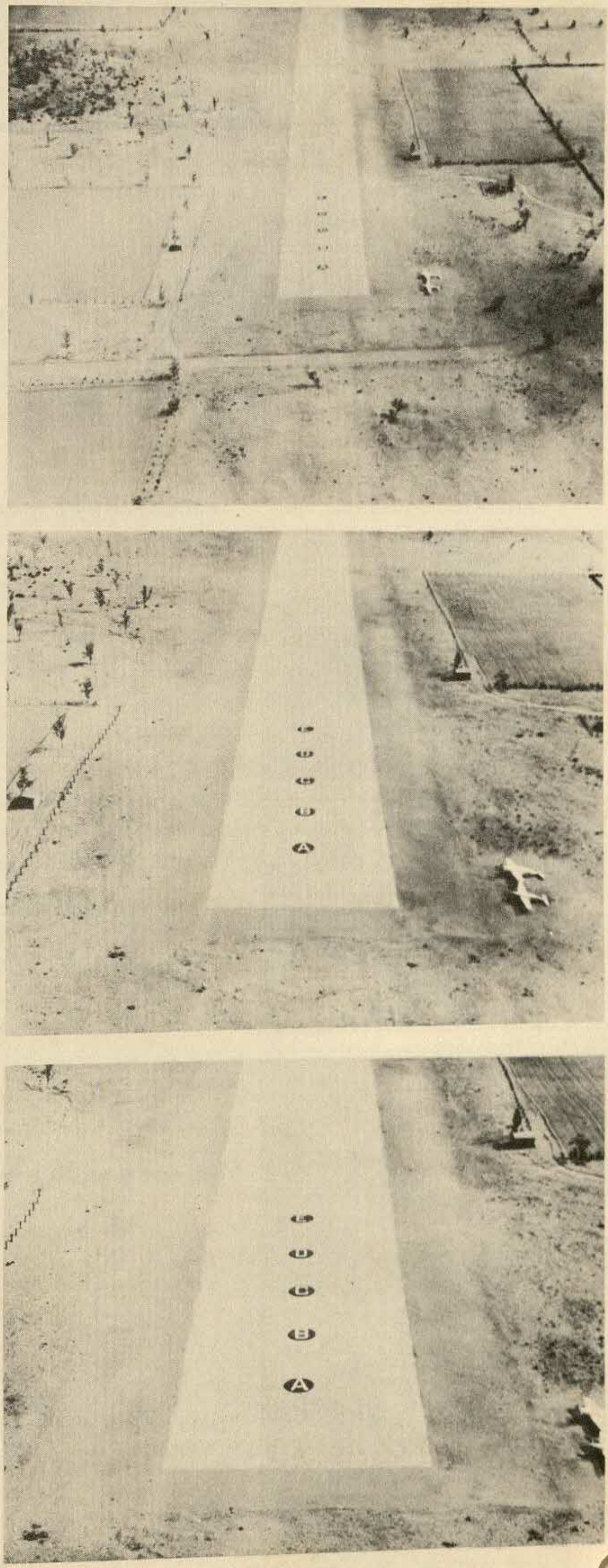
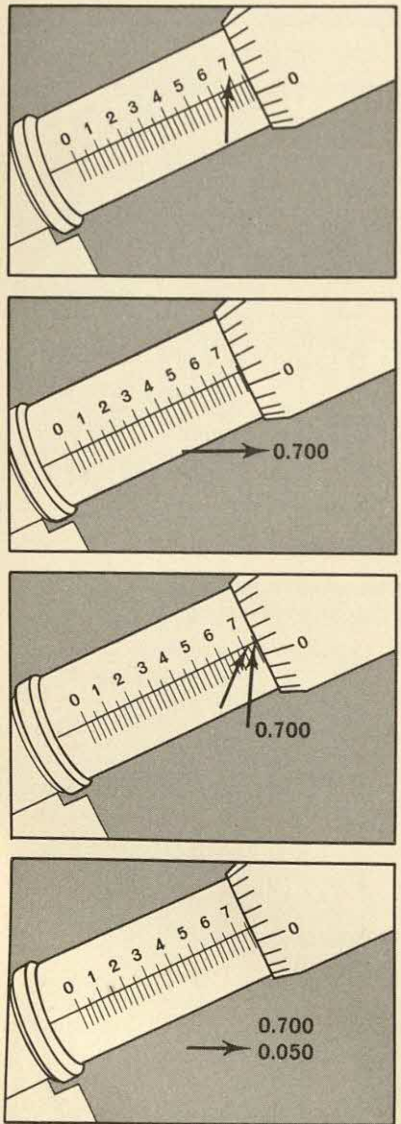


FIGURE 13.3. *Successive appearances of a runway during a landing glide. (From Gibson, J. J., The perception of the visual world. Boston: Houghton Mifflin, 1950)*

considerable. Perhaps, though, the clearest effect of this technique in training is simply to insure that the stimulus situation is the same for the screen-watcher as if he were actually present in the scene being shown. In other words, because of a high degree of similarity between the training situation and the job, positive transfer may be expected with the use of this motion picture technique.

FIGURE 13.4. *Four steps in a sequence for reading a micrometer, from a training film on this subject. Animation used in this film provides a form of reinforcement to the learner. (From Lumsdaine, A. A.,* The influence of simple animation techniques on the value of a training film. *Washington, D. C.: Headquarters Command, Bolling Air Force Base, HRRL Report No. 24, April 1951)*

ANIMATED PICTURE: **ACCOMPANYING NARRATION:**



"[The reading] is determined by first referring to the scale on the barrel. The figure seven. . .

". . . indicates seven hundred thousandths.

"Two more graduations are seen.

"That's another 0.050. which is fifty thousandths. . .

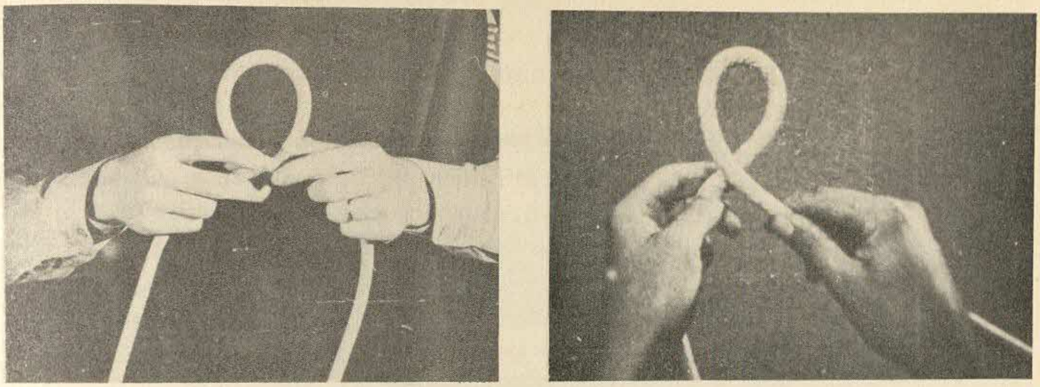


FIGURE 13.5. *Single frames from two comparison films on knot-tying showing the "objective" and "subjective" points of view of the camera. (From Roshal, S. M., Effects of learner representation in film-mediated perceptual-motor learning. State College, Pennsylvania: Pennsylvania State College Instructional Film Research Program, December 1949)*

Training Procedural Sequences

Motion pictures have been much used to make possible the learning of sequences. For example, Figure 13.4 shows the main steps in the sequence required for reading a micrometer. In the experimental training study performed with this film, a very considerable amount of learning was obtained after a single showing.

The effectiveness of motion pictures or television presentations in accomplishing the learning of sequences must obviously be limited by the length of the sequence to be learned. Notice, for example, that the reading of a micrometer is essentially a four-step sequence (or at most a six-step one, if we allow for the steps requiring addition). There are many such short sequences required in various industrial operations. For these, we should expect audio-visual training to be quite effective. But, as we have seen in Chapter 6, the process of learning long sequences brings the learner up against intra-sequence interference, and consequently requires many more practice trials to achieve success. For this reason, we should expect the training of long procedural sequences by audio-visual means to be only as effective as other ways of producing single-trial learning.

Training for the Learning of Models

As we have seen, motion pictures have the unique characteristic of being able to portray dynamic models. One successful use of movie presentations, for example, has been in training Air Force navigators who must learn to identify the complex and constantly changing patterns of terrain features on a radar scope. A simpler example is the identification learning involved in tying knots with a rope. Single frames from two such films are shown in Figure 13.5.

The study which used this film was designed to test the effectiveness of several different variables in motion picture presentation. Of particular interest were (1) the depiction of motion as opposed to static shots of the knot at various stages of completion; and (2) the showing of knot-tying from the standpoint of the participant rather than the external observer. The latter contrast was provided by constructing one form of the film with the camera looking over the actor's shoulder ("subjective camera," or 0° angle of photography), and another with the camera viewing the action from the side ("objective camera," or 180° angle of photography).

The performance of a large number of naval trainees in tying the bowline, sheet bend, and spanish bowline knots was tested immediately following the viewing of a film devoted to the respective knot. The proportions who were successful following the showing of each type of film are shown in Figure 13.6.

FIGURE 13.6. *Comparison of effectiveness of motion picture characteristics in an experimental training film on knot-tying. A. compares the proportion of individuals correctly tying three knots after seeing a film using motion shots (N = 840) and the proportion in a similar group (N = 826) after seeing a film using static shots. B. is a comparison of proportions of individuals correctly tying the knots after observing a film whose sequences were photographed from 0° (N = 833) and the proportion in another group which saw a film with sequences photographed from 180° (N = 823.) (Data from Roshal, S. M., Effects of learner representation in film-mediated perceptual-motor learning. State College, Pennsylvania: Pennsylvania State College Instructional Film Research Program, December 1949)*

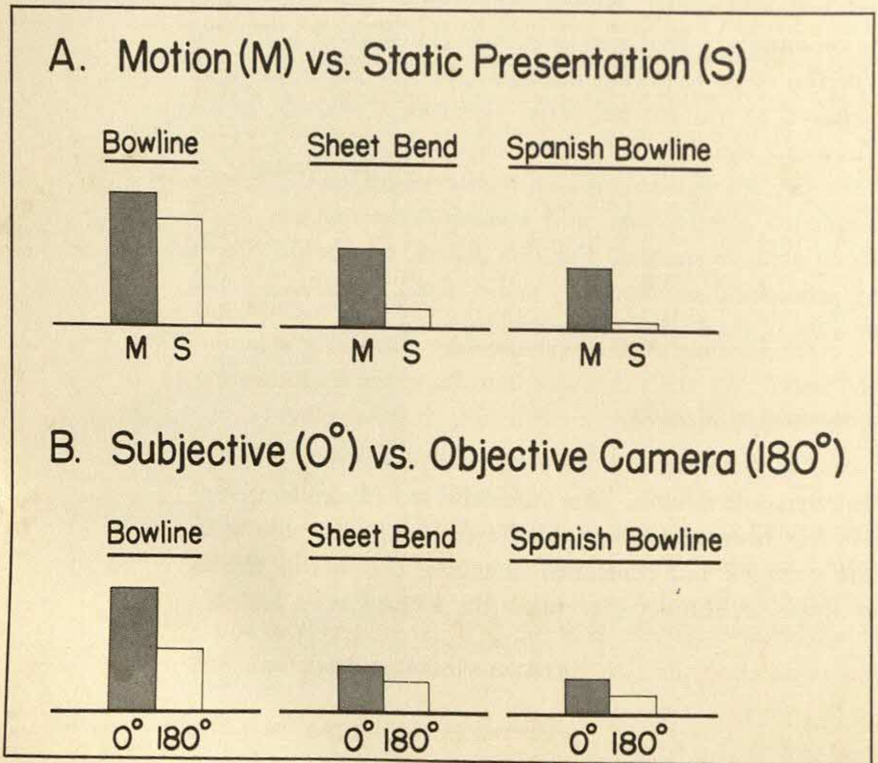
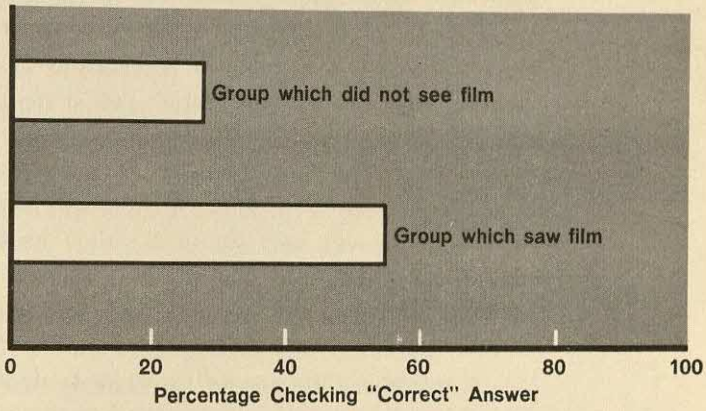


FIGURE 13.7. *Change in a concept produced by showing the film "Battle of Britain" to Army basic trainees. The percentage of men checking the "correct" answer is compared in a group which saw the film with this percentage in a group which did not. Question: "The way the Nazis originally planned to conquer Britain was to. . . ." Correct answer: "destroy the RAF, then invade England with paratroops and panzer divisions." (Data from Hovland, C. I., Lumsdaine, A. A., and Sheffield, F. D.,* Experiments on mass communication. *Princeton: Princeton Univ. Press, 1949)*



Presumably, the film which depicted motion was more effective for training because it presented some of the dynamic features of the models being required. Similarly, a more direct view of these dynamic models was provided by the "subjective" camera angle than by views taken from the side. It is possible also that some reinforcement value derives from this type of presentation, owing to the more directly visible correct actions.

Training in Concepts

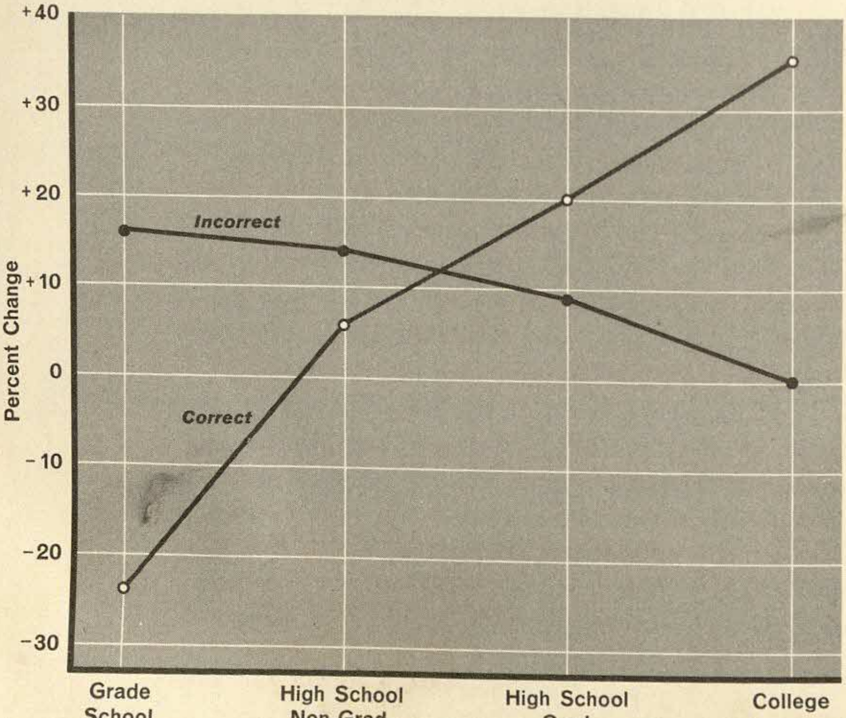
Motion pictures and television have been extensively used for the conduct of training that involves the learning of concepts. One of the most extensive studies of the use of motion pictures for this purpose was carried out during World War II in connection with the Army's orientation program on "Why We Fight." A series of films was designed for widespread showing to new recruits during basic training. The stated purpose was "to acquaint members of the Army with factual information as to the causes, the events leading up to our entry into the war, and the principles for which we are fighting." Thus, while the fundamental purpose of the program was to alter or reinforce certain attitudes, this was done by conveying information in the form of "facts." We shall consider here some results indicating the effectiveness of these motion pictures in inducing such learning.

A typical finding following the showing of the film "Battle of Britain" is shown in Figure 13.7. A much greater proportion of men acquired the concept desired from seeing the film, as compared with a control group of men who did not see the film. This is one example of concept-learning chosen from many similar results obtained with Army films.

Are films of this sort more or less effective at different levels of intellectual ability? This is another question the Army investigators attempted to answer by their studies. It is conceivable, after all, that these particular films may have been most helpful in establishing concepts in people of lower levels of intelligence, whereas those of higher intellect may have been less affected, because of boredom or inattention. The results show, however, that the reverse is the case, at least so far as these films were concerned. A questionnaire was administered to groups of trainees observing the films "The Nazis Strike" and "Divide and Conquer" both before and after the showing of the films. A count was made of the number of changes in *correct* answers, and also of *incorrect* answers, for groups of different educational levels. (In such a group, there is typically a high correlation between intelligence, as measured by a test, and educational level; and this was the case here). The findings are shown in Figure 13.8.

It would not be correct to conclude that this kind of finding would extend to all types of training films. It is reasonable to expect that, for concept learning, motion picture films become more effective as the intelligence of the audience increases. On the other hand, we know from other evidence that when nonverbal skills or models are to be acquired, training films appear to have an advantage over lectures, particularly for individuals of relatively low verbal ability.

FIGURE 13.8. *Effectiveness of the Army orientation films "The Nazis Strike" and "Divide and Conquer" in producing concept-learning in trainees of different educational levels. Changes are shown in the percentage of correct and incorrect answers following the showing of these films. (After Hovland, C. I., Lumsdaine, A. A., and Sheffield, F. D.,* Experiments on mass communication. *Princeton: Princeton Univ. Press, 1949)*



Changing Attitudes

A number of studies have demonstrated the effectiveness of motion pictures and television programs in producing changes in attitudes. Generally speaking, no outstanding advantages appear to be inherent in this type of training medium over the lecture, for this purpose. This was the finding, for example, in the Army studies referred to above when attitudes of the trainees were measured toward such things as German military efficiency, Allied appeasement, Allied defensive strategy, and resentment toward the Nazis.

TRAINING DEVICES

Another medium which can be used with great success in a training program is the class of specially designed units of equipment called *training devices.* The basic aim of such devices is to provide a set of conditions within which learning appropriate to the job will take place. To the extent that a training device fosters the desired learning, it can be said to "take over" the learning situation from the instructor.

The advantages of this use of the training device to determine the learning situation are several. First, the *representation of the essential stimuli* can often be accomplished by the device when this is not possible to the instructor (except, of course, to the extent that he may do so with visual aids). This means that the conditions for transfer to the job, dependent as they are on similarity of stimuli, can often be better represented by a training device. Second, the *conditions of reinforcement* are frequently better handled by a training device than by an instructor. The instructor may find it difficult, even when he is dealing with an individual student, to provide "knowledge of results," including correction of errors, at just the right times to make learning most efficient. The training device can provide reinforcement immediately and automatically. In the third place, the training device is usually specifically designed to provide for *frequent practice,* and even for overlearning, with its well-known results for retention and transfer. For the training of those human skills which cannot be acquired in the single-trial learning situation provided by the lecture or film, this characteristic can be a crucial advantage.

Types of Training Devices

Training devices may be designed to produce learning of various human functions—verbal sequences, motor skills, models, and concepts.

However, practical and economic factors limit their usefulness in certain areas. For example, a training device can easily be designed to accomplish the kind of one-trial learning that takes place in a lecture or a television presentation. But this would in most cases be quite uneconomical. Alternatively, a training device may be built to provide practice in job skills. But this is also uneconomical in many instances, because the actual equipment of the job may be more readily available. For example, one would not ordinarily design a training device for the learning of bicycle-riding, or typing, or rifle-shooting. It is more convenient in these instances to employ an actual bicycle or typewriter or rifle. The usefulness of training devices occurs in an area between these two extremes. The training device is not economical when the appropriate conditions of learning and transfer can be more simply represented either by verbal and pictorial means (as in a lecture, book, or film), or when they can be created in the job situation itself.

Within these limitations, several types of training devices have been found to have considerable effectiveness for learning. There are *skill trainers,* which are used to provide practice in motor skills. Somewhat less well-known, but none the less effective, are *concept trainers,* which can be used to establish the rules and principles essential for transfer to job performances. Finally, there are *simulators,* or job performance trainers, which are used to establish and maintain high degrees of proficiency in job activities.

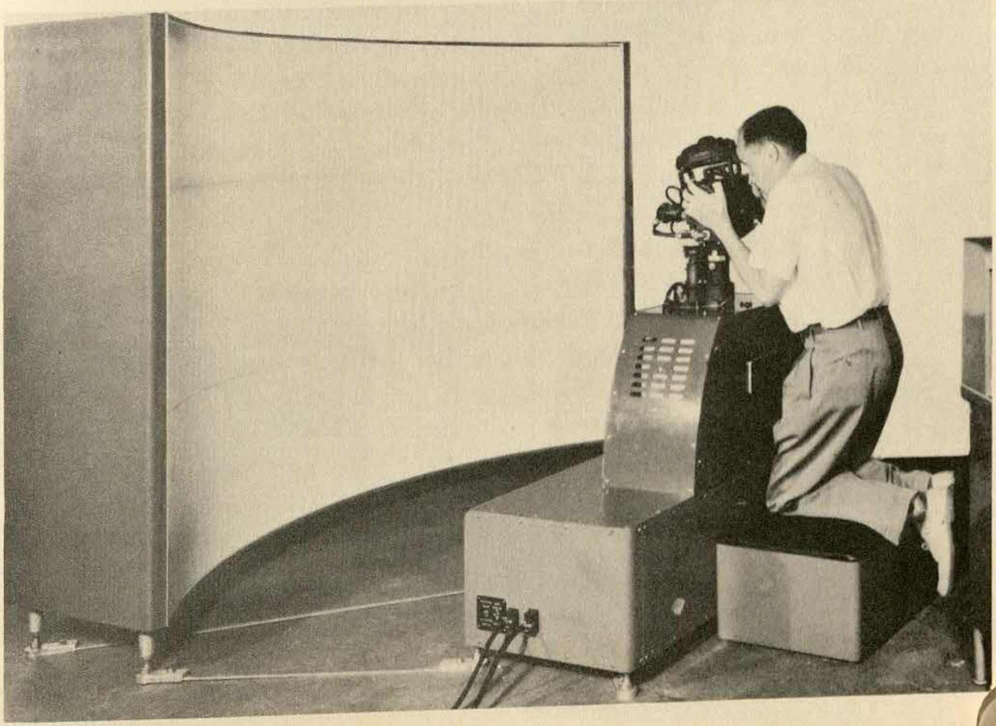
Motor-Skill Training

As we have seen (Chapter 8), the learning of motor skills often requires considerable practice. Furthermore, this practice must provide for immediate reinforcement, in order that correct responses become connected through the process of learning with the stimuli of the external environment, as well as with kinesthetic stimuli. For many types of job skills, sufficient practice and efficient reinforcement conditions may be difficult to arrange. For the skills of maneuvering a plane, for example, there is the danger involved for the novice to practice in a real plane, and the expense of providing sufficient practice. For skills of various types of gunnery, particularly aerial gunnery, an additional factor may be the difficulty in providing immediate reinforcement, since the target to be hit is frequently so far removed from the location of the firing station that the correctness or incorrectness of motor responses cannot be directly seen. In such situations, training devices have a practical value.

An example of a device for the learning of flexible gunnery (the direction of fire power from a bomber to an attacking fighter by visual tracking) is shown in Figure 13.9. The trainer is composed of an actual sighting and gunnery station by means of which tracking and triggering is carried out. Attacking planes are represented by projection on a curved screen, where the images of the planes follow typical attack courses. The attacking plane is correctly framed, and being "hit," when the projected central pipper of the reticle is on the center of the projected plane, and simultaneously the circle of dots (representing range) frames the wing tips of the plane. The skill being acquired is a kind of three-dimensional tracking, the dimensions being azimuth, elevation, and range. The success of the gunner in maintaining a correct sighting picture in each dimension during an attack is immediately apparent to him by comparison of the projected plane and the projected reticle. Thus he has immediate "knowledge of results." The trainer also has provision for scoring his performance during each attack (in terms of "time-on-target"), making it possible to use his own achievement as a motivating factor for learning.

Figure 13.10 indicates the improvement in performance of flexible gunnery skill measured during thirty minutes of practice, over several days. Time-on-target scores are shown for each dimension of the task (azimuth, elevation, framing) as well as for the total task. The trainer is effective in improving skill, but the learning effects are greatest at the beginning of practice, as might be expected. Of course, there may also be benefits from overlearning, but these were not evaluated for this trainer.

FIGURE 13.9. *A flexible gunnery trainer, for the training of visual tracking skill, involved in destroying an attacking fighter aircraft. This type of gunnery system was employed in bomber aircraft of the United States Air Force during World War II. (Courtesy Mast Development Company)*



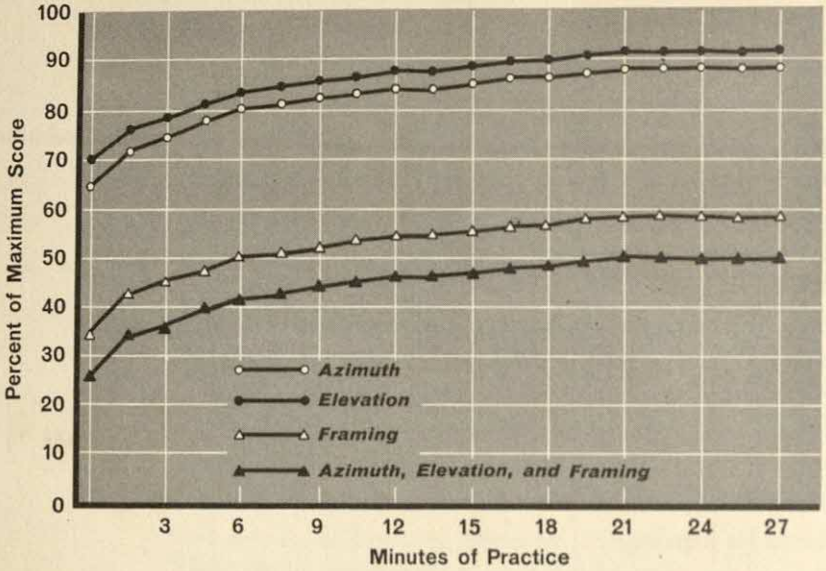


FIGURE 13.10. *Improvement in performance in a flexible gunnery task during thirty minutes of practice distributed over several days. Scores are shown in percent of maximum possible score for tracking in azimuth, elevation, and framing (range) separately, and for a total time-on-target score which includes these three components of performance. (After Goldstein, M., and Ellis, D. S.,* Pedestal sight gunnery skills: A review of research. *Lackland Air Force Base, Texas: AFPTRC Report TN-56-31, February 1956)*

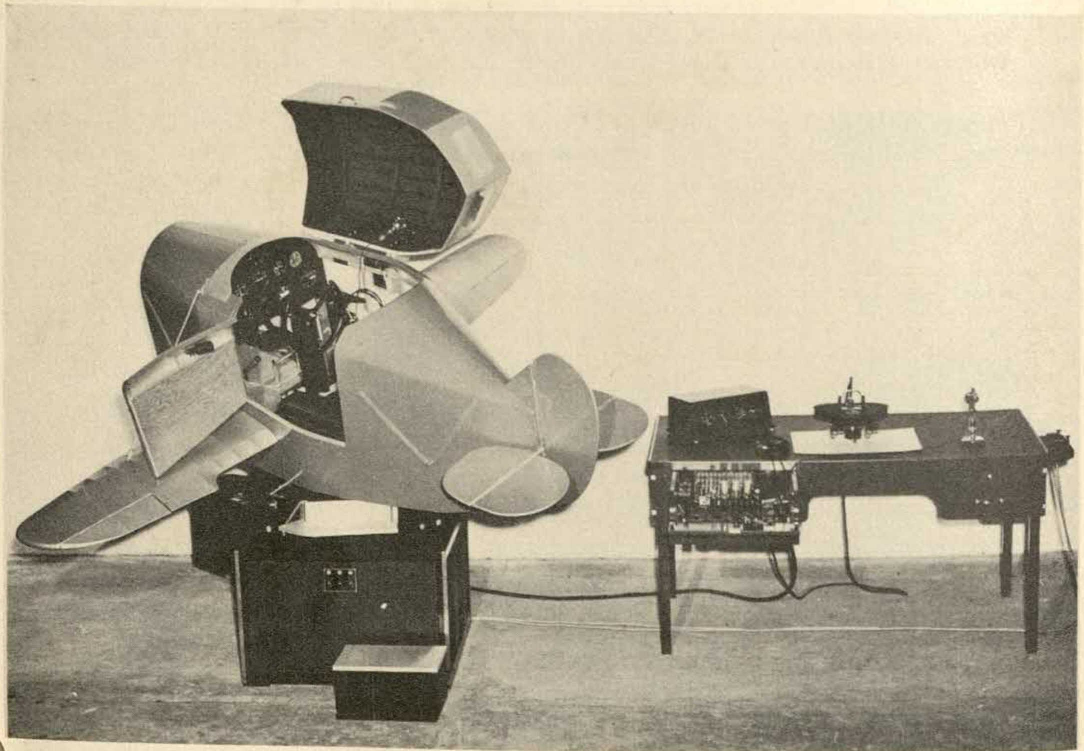


FIGURE 13.11. *One of the early models of a flight trainer. This model is still in wide use throughout the country. It provides basic training in flying "on instruments." (Courtesy of Link Aviation, Inc.)*

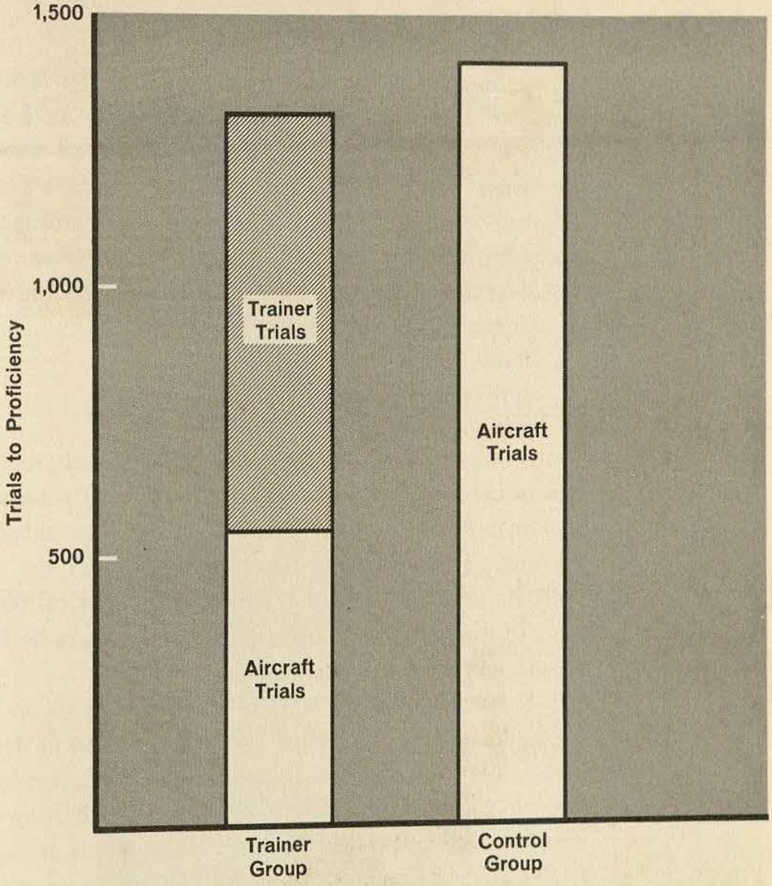


FIGURE 13.12. *Trials required to reach standard proficiency in 13 exercises of elementary flying training. One group practiced each exercise in the training device first, and later in the aircraft. The control group began and continued practice in the aircraft. The treatment of the trainer group resulted in a saving of 100 total trials, or 874 aircraft trials. (Data from Williams, A. C., Jr., and Flexman, R. E.,* Evaluation of the Link SNJ operational trainer as an aid in contact flight training, *SDC Technical Report 71-16-5, 1949)*

Another example of skill training comes from the use of a flight trainer to train student pilots in maneuvers in light aircraft. Matched groups of students were given practice in thirteen exercises including basic maneuvers like turns, climbs, glides, and traffic pattern flying. One group learned each exercise first in the flight trainer, then proceeded to practice the exercise in the aircraft. A second group began and continued practice in the aircraft, without any practice in the training device. A record was made of how many trials of practice were required of the individuals in each group to meet certain standards of proficiency for each exercise, carefully administered by instructors in the aircraft. The results are shown in Figure 13.12. The trainer group required a total of 1,318 trials to meet the proficiency standards, 544 in the aircraft and 774 in the trainer. The control group required 1,418 trials in the aircraft. Thus the savings in trials was 100. For practical purposes of saving expensive aircraft time, it may be noted that the trainer group was able to meet the required proficiency standards with a saving of 1,418 −544, or 874 *aircraft trials*, a reduction of 62 percent. This study provides an excellent example of the practical effectiveness of training devices in elementary flight training, a finding which has been verified on a number of occasions.

Concept Training

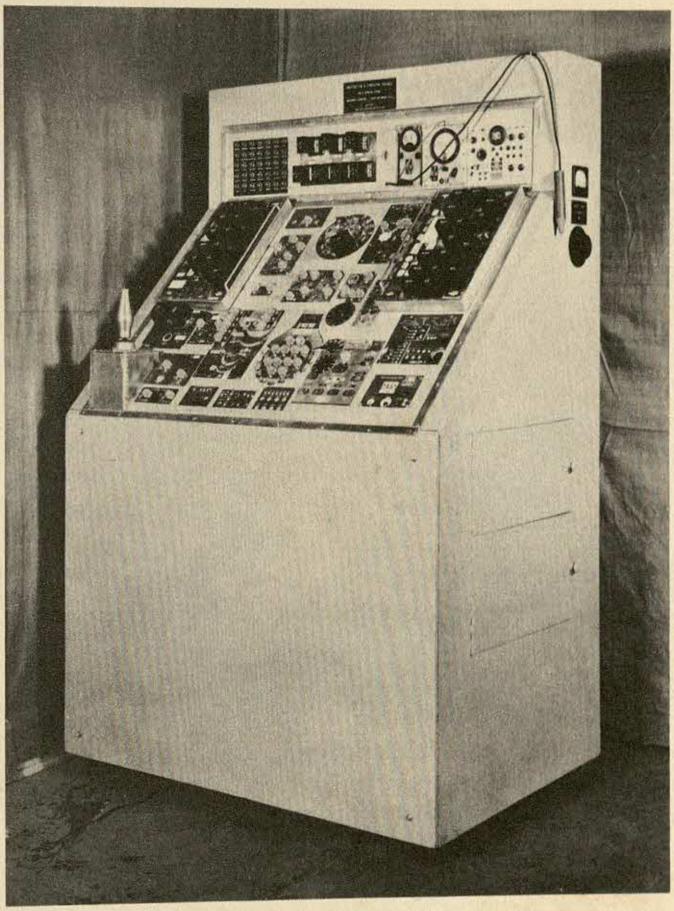
As we have seen, lectures and audio-visual presentations are quite effective in producing learning of certain types of concepts. However, there are also instances when the limitations of these media become apparent in training. Particularly is this true when: (1) the concepts to be learned must be aroused in the job situation by physical objects and stimuli rather than by verbal stimuli and (2) the concepts to be learned are too complex for mastery in one or two trials.

Examples of these sorts of concepts are to be found in the repertoire of the technician who must find malfunctions in complex electronic equipment. Such a technician must learn conceptual rules governing the flow of current through an electronic system, which rules are aroused by instrument readings, wave forms, or other physical stimuli from the equipment. In evaluating a man's fitness for this job, it is not so important to know whether he can answer the verbal question "How does the current flow through this component?" as it is to know that he can actually trace the current flow in response to instrument readings or other physical checks. It is important for transfer, therefore, that he practice these rules *in connection with* the relevant instrument readings.

In addition, the concepts used by an electronic-equipment technician are complex. Although these rules can be expressed in words, such expression gets quite lengthy. For this reason the concepts of system-functioning to be learned by the technician require more than one or two trials of practice; in fact, they often require dozens of trials for mastery. This amount of practice can be successfully provided by a training device.

The decision to employ a training device for complex concept learning in a training program must of course be based on some reasons providing an advantage over the use of actual equipment in the setting of the job. Of course, actual equipment can be used to provide practice leading to the acquisition of concepts. But it is often inconvenient and expensive to do so. If the equipment itself is costly, there is the risk that a trainee may damage it. The repair and readjustment of such equipment following each trainee's

FIGURE 13.13. *A training device for training electronic technicians in utilizing the concepts of system functioning for troubleshooting complex electronic equipment. (From French, R. S., and* Martin, *L. B.,* A flight-line troubleshooting trainer for a complex electronic system: The MAC-2 Trainer. *Lackland Air Force Base, Texas: AFPTRC Report TN-57-106, July 1957)*



use may be prohibitively expensive and time-consuming. For these reasons, a training device for concept learning is often found to be both convenient and effective.

An example of a concept-training device developed by the United States Air Force is shown in Figure 13.13. The front panel of this device represents in miniature form the various components, controls, and check points of a complex airborne electronic system. A typical malfunction is "set into the system" by operating one of two hundred individual switches on the side panel. The trainee then traces down the source of this malfunction within the system, beginning by operating certain controls, and continuing by making checks at appropriate points with the probe provided. An instructor watches the trainee, and provides necessary corrective guidance if he makes illogical or unnecessary checks. By this means the student electronic technician can be provided with practice on a variety of malfunction problems of graded difficulty.

Obviously, this kind of a trainer is more convenient to use for practice, and at the same time much less expensive, than the equipment itself. By using such a device, the student is able to acquire complex concepts of system-functioning which are connected with the physical stimuli arising from a small replica of the equipment itself. Transfer to actual job activities is assured by making the components of the trainer highly similar in appearance to those of the job.

Proficiency Training

Perhaps the best-known use of training devices is as media for what is called "proficiency training." This phrase generally refers to the final stages of attainment of proficiency, and the maintenance of proficiency, in the tasks of a job. The emphasis here is on the transfer of concepts, sequences, and motor skills to the performances of the job, rather than upon their initial learning, which may have been previously accomplished by means of a lecture, film, or other training device. The proficiency trainer is often used in sessions alternating with practice on the job itself, particularly to provide practice on job skills that are not conveniently, or not frequently enough, practiced on the job itself.

Because of their purpose of establishing high proficiency in actual job activities, proficiency-training devices are built with an emphasis on "job realism." Typically, in their engineering design, attention is paid to the representation of physical characteristics of the job's equipment with great accuracy. Such devices are accordingly called *simulators*. One of the most common varieties is the *flight simulator*, used by the Air Force and by most major airlines to insure the maintenance of pilot proficiency.

A flight simulator is usually built for each new major airplane, and is designed to simulate with a high degree of accuracy the characteristics of the actual plane, insofar as these are reflected in the cockpit panels of instruments, the sound of the engines, the "feel" of the controls, and the kinds of control reactions required of the pilot. When an experienced pilot is scheduled to be assigned to an airplane with which he is unfamiliar, it is customary for him to undertake a course of a number of hours' practice in "flying" the simulator for the new airplane, before he undertakes to practice in the air. By this means, transfer of training is assured from the general skills and concepts he has as an experienced pilot, to the specific performances required by the new airplane.

In addition to its use in *establishing* specific skills applicable to a newly introduced airplane, the flight simulator is also employed to *maintain proficiency* in job performances which may be infrequently practiced. Emergency procedures fall into this category. Fortunately the airline pilot has only extremely infrequent opportunities to practice the procedures and skills required in flying his plane on two rather than four engines; or in

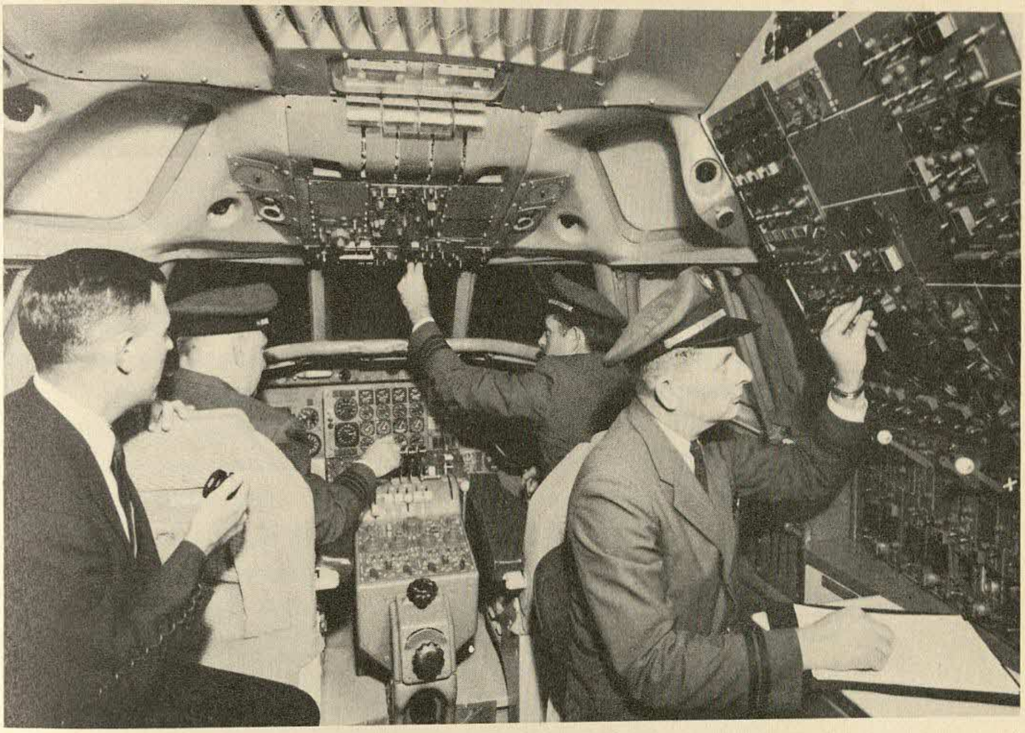


FIGURE 13.14. *A flight simulator for a modern jet aircraft. (Courtesy of Link Aviation, Inc. United Air Lines Photo.)*

handling an engine fire; or in making a belly landing. Such emergencies, as airline records show, occur with rarity during millions of miles of airplane operation. How does the pilot know what to do when and if they happen? He knows because he has practiced the correct procedures in a flight simulator which represents the plane not only during normal operation, but also during all types of emergencies. In most airlines, pilots are required to undertake such periods of practice with the flight simulator at regularly scheduled intervals. Thus the proficiency trainer has the primary purpose of maintaining proficiency in skills which are essential to the job, and yet which cannot be practiced on the job because this would be dangerous, expensive, or both.

There are many types of simulators. Their widespread use in the armed forces reflects the purpose of providing practice on realistic job activities which would be either dangerous or very expensive as a part of peacetime operations. There are simulators for tank operators, for gun operators, for radar operators, for missile crews, for submarine crews, and many others. Simulators for industrial operations are not so widely employed, apparently because of the somewhat less frequent presence of serious danger. However, there are many industrial jobs for which simulators could apparently be used to good advantage. The advent of radiation dangers in industry may well require a greater dependence on simulators, particularly to provide practice in various emergency operations.

ON-THE-JOB TRAINING

With the variety of media and gadgets available for training programs, the fact should not be lost sight of that the actual job situation is often an excellent setting for training. A great deal of training is done on the job. Sometimes, it can be assumed that the job incumbent will acquire the necessary skills, concepts, or procedures after a short early period during which slowness of performance or errors can be simply "charged up to experience." In other situations, special provisions may be made to provide the necessary practice conditions, still without making any basic changes in the job's environment or equipment. Guidance in a job situation is often essential if the worker is to acquire correct work methods, and to avoid inferior ones. Let us examine some of the major possibilities for on-the-job training.

The Learning of Procedures

Many kinds of procedures may be readily learned by practice on the job. The individual can acquire short procedures like "how to turn on a machine," "how to draw tools," "how to set up and read a test instrument," in a very few trials of practice, perhaps with the aid of a set of printed instructions. For such sequences, the period of learning is short and therefore there is a relatively insignificant delay in the attainment of acceptable proficiency in the job.

Longer procedures, such as those required on a milk delivery route, or in many varieties of replacement of parts in maintaining equipment, or in processing packages for shipment, naturally require much longer periods of practice by the new job incumbent. This is one of the primary reasons for the use of the "apprentice system," in which the new worker is "checked out" on the job by an older experienced worker over a period of weeks or months. During this time, the required procedures may be learned a little at a time. That is, the new worker typically takes over a greater and greater proportion of the duties of the job until he can perform all of them satisfactorily. The experienced worker in this setting acts as a tutor. He tells the novice what steps are involved in the procedure to be learned, and then permits him to practice these steps, in progressively longer sequences. It is also his responsibility to observe the performance of the new worker, and thereby to judge when the procedures of the job are being adequately performed.

An interesting use of a training device for the learning of long sequences in the actual job situation is illustrated in Figure 13.15. Here the worker is pictured practicing relatively lengthy sequences of equipment adjustment and replacement while seated at his bench watching a small motion picture screen. The device is a magazine-loading motion picture projector developed for Air Force use in this type of on-the-job training. The learner, after inserting a magazine of film depicting the procedure to be learned, is enabled to stop and start the sequence at will. This means that he can choose his own pace for the learning of a new procedure, breaking the total sequence into short steps, and then actually carrying out these steps. Such a device makes an instructor or "tutor" unnecessary for certain tasks, and insures a rapid transition from the learning of a procedure to its performance in the job situation.

Learning Motor Skills

Unless they are very simple ones, motor skills typically require a good deal of practice for mastery, as we have seen. Skills like those of driving a truck, operating a power shovel, flying a helicopter, take a great deal of time to learn. For many skills of this sort, initial learning cannot be brought about in the actual job situation, in any true sense. Training devices and

FIGURE 13.15. *A technician learning an equipment-adjustment procedure in an on-the-job situation. The worker watches individual steps on the small screen, stops the projector at will, and proceeds to carry out these steps on the actual equipment. In this way learning of the total procedure is integrated with actual performance on the job.*

simulators are often the most economical way of accomplishing the acquisition of the required skill. However, this does not mean that the actual equipment may not be used for such training. It often is. The skills needed in truck driving are typically learned in an actual truck; and a similar statement can be made for the power shovel and the helicopter. What this amounts to is that the equipment of the job is being used, during the period of initial skill learning, as a training device.

Once initial learning of skills has been accomplished, however, the job situation provides the necessary setting for transfer of training. For example, the experienced truck driver may readily transfer his skill to the operation of a new truck (or one that is unfamiliar to him) in the job situation. Or the typist may transfer her skills to the operation of an electric typewriter having acquired these skills initially on a non-electric one. The period of on-the-job training may be characterized by some slowness in operation or by an increased number of errors, or both. But positive transfer is usually high, provided there is a high degree of resemblance of the two situations (see Chapter 6). For motor skills, on-the-job training is typically employed successfully for the transfer of previously acquired skills to the specific situation of the job.

Learning Concepts and Problem-Solving

The job situation is also a good one in which to acquire the necessary concepts for adequate performance. As we have pointed out, the initial learning of a new job may often be aided by the use of lectures, films, or training devices. The success of these, however, may depend upon the faithfulness with which they represent and get across to the learner the exact concepts he needs. Sometimes this is a very difficult thing to do. The job situation has the advantage, as a training setting, of being exactly representative.

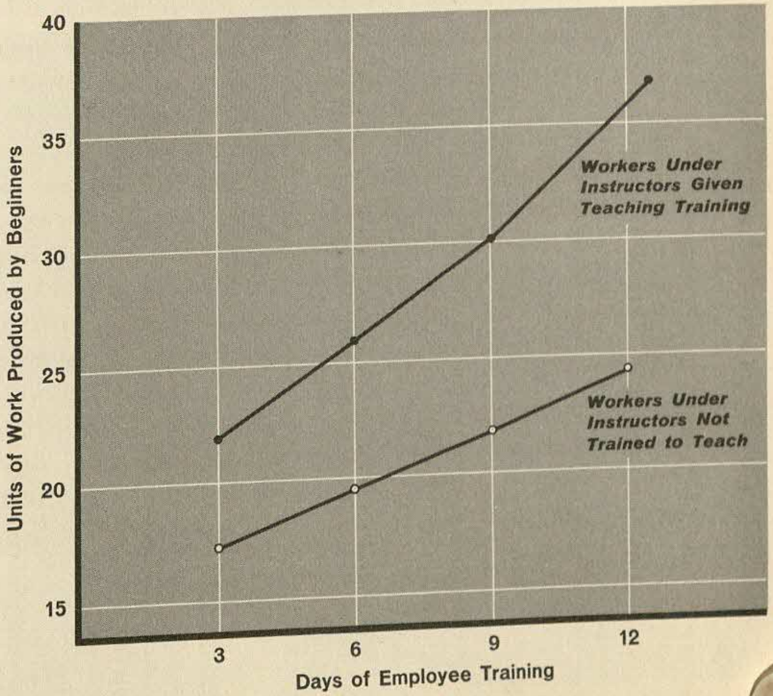
There are many jobs for which the acquisition of required concepts, and their use in solving problems, occurs with apparently greatest efficiency by means of on-the-job practice. For example, a new salesman may learn a number of important rules and principles from a lecture or training film. But he is able to acquire other important ones, and to learn to use them effectively in solving each individual sales problem, by practicing selling. Certainly the transfer of acquired rules to the solution of such problems can best occur by means of practical experience on the job. No sales organization would imagine that a salesman could achieve mastery of his job without such on-the-job training.

On-the-job training has often been used in training junior executives. A system of "apprenticeships" is usually established, in which the individual is exposed to concepts of management in various departments and then is permitted to solve increasingly complex management problems. Such procedures can be expected to result in considerable transfer of a variety of management concepts to jobs of increasing scope and responsibility.

On-the-job training has the advantage of providing individualized instruction which takes into consideration the facts of individual differences. However, the success of such a program depends heavily on the skill of the immediate supervisor. In fact, there are programs which attempt to teach supervisors how to train. Figure 13.16 shows the results of one study in which trainers were trained. It can be seen that beginning workers did much better when trained by instructors who themselves had been trained.

In the chapter on Social Behavior we saw the importance of the supervisor's example on his subordinate's behavior. Training supervisors in a formal training program was shown to be less effective than the informal "training" he got from the "leadership climate" under which he worked. It is important to recognize that supervisors are continually shaping their subordinates' behavior on the job through the patterns of reinforcement they provide. Take the common example of punctuality. Suppose that a

FIGURE 13.16. *Comparison of employee learning of stitching operations when their instructors were trained and when they were untrained. The training for instructors emphasized methods for increasing motivation, techniques for establishing favorable social relationships, and ways of guiding trainees. The trainees who began their training under the trained instructors learned faster and achieved high proficiency. (Data from Maier, N. R. L.,* Psychology in industry. *Boston: Houghton Mifflin, 1955. After Bavelas)*



company's rules say that 8 o'clock is starting time. What the subordinate learns about punctuality is directly attributable to his supervisor—for example, in a particular department, reporting for work at any time after 8:06 is likely to result in a reprimand. Similarly, tolerances in work quality are often a function of how the worker perceives his supervisor's reaction to them. In many such subtle ways, the supervisor is continually "training" the worker in attitudes and skills.

CASE METHOD, GROUP DISCUSSION, AND ROLE-PLAYING

Several training methods cannot readily be associated with a single medium. These methods represent recent departures from traditional approaches to training. Essentially, these methods make maximal use of group participation in the learning process. In so doing, they have two advantages. They motivate the trainee through group involvement, and they provide opportunity to practice actively certain types of performances dependent on concepts. These methods have recently been used extensively in management training programs, where the primary aim has been to develop skill in problem-solving and in desirable social behavior in the job situation.

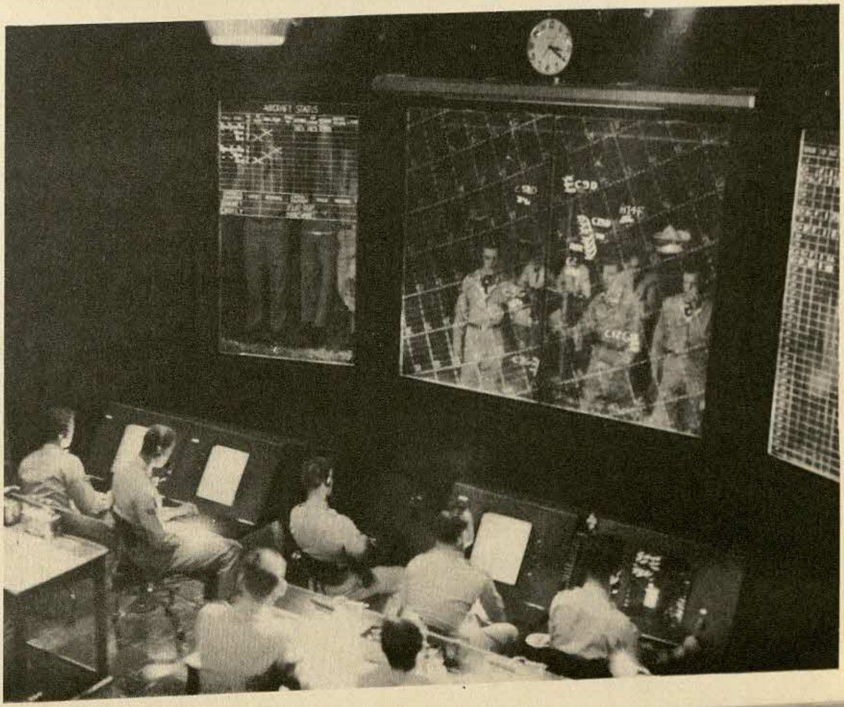
With the *case method*, a complex "real-life" situation is presented to a small group. Typically, this is a printed description of an industrial or business problem which may extend over several pages, and may include a variety of matters such as personalities of individuals, costs of raw materials, communication problems, scheduling difficulties, etc. The group discusses the case with a view to identifying and analyzing the problem, and suggests possible alternative solutions. Some training programs rely heavily on the case method alone. It seems reasonable, however, that this approach, even with a skilled discussion leader, is best utilized in conjunction with other approaches. For example, no one would advocate that the case method be used exclusively to train medical doctors. Such individuals must first learn basic concepts and principles, by lecture, from books, and by other methods. The case method then becomes valuable as an opportunity to *practice* and apply these principles to facilitate transfer to the job situation. The same may be said for the use of the case method in management training.

Group discussion methods are now widely used in industrial training settings, as well as in universities. They are especially useful in keeping motivation high and providing communication channels back to the instructor concerning sources of difficulty among trainees. Group discussion is time-consuming, and seems best adapted to intensive exploration of the most important course content, when the organization of the subject-matter has been derived from other sources (for example, from a lecture). Discussion methods are particularly useful in modifying attitudes, and in bringing about understanding of controversial or confusing topics.

For groups which themselves are organized to carry out a particular set of operations, discussion of group performance in "de-briefing" sessions following practice exercises can be a highly effective training method. In one study using this method, a crew of nearly 40 men practiced carrying out the operations of an air-defense direction center like that shown in Figure 13.17. The task of the group was that of defending an area of 100,000 square miles against air attack. In successive practice exercises, the simulated load of air traffic, including numbers of "enemy" planes, was progressively increased. At the end of the study the load was three times as heavy as in the beginning.

Following each practice session, the group was given information about its performance, and this information was discussed by the group members in a "de-briefing" period. During this time, the group devised many new ways of correcting errors and improving the efficiency of operations, which were then put into effect during the next exercise. In this manner, discussion made it possible for the group to invent and put into effect new con-

FIGURE 13.17. *The operations room of a simulated air-defense direction center. (From Chapman, R. L. and Kennedy, J. L., The background and implications of the Systems Research Laboratory studies. In Finch, G., and Cameron, F. (Eds.),* Symposium on Air Force human engineering, personnel and training research. *ARDC Technical Report 56-8, 1956)*



ceptual rules that maintained the effectiveness of group operations in the face of constantly increasing complexity.

Role-playing has been used as a training method in such various settings as mental institutions, management training programs, and universities. The technique is most useful in providing individuals with practice in desired types of social behavior. The technique also has been used to develop insights into the feelings and attitudes of oneself and others. In practice, an imaginary problem situation is set up in which various persons are assigned statuses and roles, and then act out these parts. After a brief period, the role-playing is interrupted and the participants discuss their feelings, their own behavior, and the behavior of others. Often nonparticipating trainees who have observed the action may be asked to come up and substitute in one of the roles; or participants may be required to switch roles. Thus, a foreman may play the role of a new worker, or a Negro worker, or his own supervisor in relation to a given problem. A mental patient, about to be discharged, may first play the role of meeting her neighbor on the street for the first time. Such programs need to be conducted by a skilled instructor, who must encourage the individuals to "get into the spirit" of their roles. As with the case method, role-playing techniques are more likely to be effective after the trainees have learned relevant concepts and principles. With mental patients, this technique is usually effective only if they have already gained considerable control over their own behavior.

SUMMARY

Training refers to the specific set of conditions used to increase the level of performance of human functions by means of learning. The arrangement of these conditions may be more or less deliberate and well organized ranging from the informal training conducted by parents and associates to the highly organized conditions of learning established in schools and industrial plants. This chapter confines its attention primarily to training conducted for the purpose of establishing the necessary levels of performance in jobs.

Training for particular jobs is usually concerned with the *learning* of specific skills and with the *transfer of training* of abilities and skills to specific job performances. Sometimes, however, training for a job must include the learning of more general abilities not previously acquired.

The principles of learning and transfer of training described in Chapter 6 may be directly applied to the design of training programs. The learning of sequences, models, motor skills, and concepts are undertaken in training programs. Learning requires the establishment of proper conditions of *motivation,* such as relating the training program to the individual's desire for advancement, or to his achievement motives and other needs. *Practice* of the performances being learned is of great importance to the success of training, as is the provision of *reinforcement,* or feedback to the learner after each practice trial. *Freedom from emotion* is a condition of learning which requires the removal of distracting or upsetting stimulation.

Transfer of training is a highly important aim of training programs. Transfer increases with the *degree of learning,* and with *similarity* of the training and job situations. For this reason, training situations need to be *realistic* and to represent the *variety* of stimuli to be encountered on the job. Evaluation of training is best accomplished by means of transfer measures, in terms of specific job *criteria.*

Four major classes of *training media* are *verbal media,* including books and lectures; *audio-visual media,* including motion pictures and television; *training devices;* and the *job situation* itself. Some of these media are most successful in training certain types of human skills and abilities, some with other types.

Both lectures and books (training manuals) are successfully employed for the learning of conceptual materials. The lecture is typically less versatile than a book insofar as it tends to be limited to presentation of single trials of learning. Concepts of classes, rules, and attitudes may often be readily acquired in this way. The lecture is ineffective in establishing verbal sequences (procedures), except for very short ones, since these typically require lengthier practice to overcome internal interference. Verbal media are also relatively ineffective as a learning situation for perceptual models and for motor skills, since they cannot present the proper nonverbal stimuli.

Audio-visual media, particularly motion pictures and television, are widely used for training. In their least complex form, such training presentations are simply "canned" lectures. Motion pictures, because of their technical versatility, can be used to exploit certain unique features of audio-visual media. These include the representation of *dynamic events,* the *consequences of action,* and the *learner's point of view.* Audio-visual media have been employed with considerable success to bring about the learning of short procedural sequences, of models required for identification, and of concepts. Generally, motion picture or television sequences constitute examples of single-trial learning, and their effectiveness is circumscribed by this characteristic. For example, long procedural sequences cannot be taught effectively in this manner.

Training devices are designed to provide a structured set of conditions within which learning of job tasks will take place. They are often advantageous in *representing the essential stimuli* of the task to be learned, in providing favorable *conditions of reinforcement* and opportunity for *frequent practice*. *Skill trainers* like flight trainers and gunnery trainers are used to provide practice in motor skills. *Concept trainers* make possible the learning of rules and principles for transfer to the job. *Simulators* are used for establishing and maintaining high levels of proficiency in skills.

On-the-job training is used to establish skills that are readily acquired during short periods of job experience, as well as to insure transfer of previously acquired skills to the job situation. Procedures, motor skills, and concepts may be effectively learned with this medium. This is particularly true for the use of concepts in tasks of the job that require judgment and problem-solving.

Several training methods cannot readily be associated with particular media. In the *case method*, printed descriptions of industrial or business problems may be used in the training of management personnel to provide practice in a variety of principles. *Group discussion methods* are useful in keeping motivation high and in providing feedback to trainees and instructor. *Role-playing* techniques are also used to provide individuals with practice in desired types of social behavior.

READING REFERENCES

Bellows, R. M., *Psychology of personnel in business and industry* (2nd Ed.). New York: Prentice-Hall, 1954. A textbook on personnel psychology, including principles of training in industry.

Fryer, D. H., Feinberg, M. R., and Zalkind, S. S., *Developing people in industry*. New York: Harper, 1956. A description of industrial training methods and results.

Ghiselli, E. E., and Brown, C. W., *Personnel and industrial psychology* (2nd Ed.). New York: McGraw-Hill, 1955. Another textbook containing material on training in industry.

Hovland, C. I., Lumsdaine, A. A., and Sheffield, F. D., *Experiments on mass communication*. Princeton, N. J.: Princeton University Press, 1949. An account of a series of studies conducted during World War II, concerned with the effectiveness of motion pictures and related media in bringing about the learning of concepts about the war by American soldiers.

Ryan, T. A., and Smith, P. C., *Principles of industrial psychology*. New York: Ronald, 1954. A text on industrial psychology with chapters on efficiency, methods of work, and the facilitation of learning.

Wolfle, D., Training. Ch. 34 in Stevens, S. S. (Ed.), *Handbook of experimental psychology*. New York: Wiley, 1951. An account of the applications of the principles of experimental psychology to training.

14

ENGINEERING PSYCHOLOGY

As we have seen, behavioral science may be put to work in designing jobs, in selecting and classifying people in these jobs, and in training the required human skills. Psychological knowledge can also be applied to the design of equipment, or, in a larger and more important sense, to the design of man-machine systems. This type of application is called engineering psychology. A number of examples of it are described in this chapter. You will learn how the engineering psychologist considers the limitations of human capacities in the design of equipment, and how in the design of man-machine systems he attempts to optimize human performance.

One of the most interesting and significant ways in which behavioral science is put to practical use is in the *design of man-machine systems.* This branch of applied effort is called *engineering psychology.* As the term implies, the psychologist engaged in this kind of work usually works as a member of a team including other types of engineers.

The design of new industrial or military operations involving both equipment and human activity is really a matter of specifying a set of interactions between man and machine. Machines that are an engineer's dream are sometimes a nightmare for the men who operate them. For a machine to operate most effectively, it must be fitted to the biological and psychological equipment of the men who work with it. Even the caveman would have benefited by having his clubs shaped and weighted to better fit his physical capacities. The growing awareness that man and machine function in relation to each other has led to the use of the term "man-machine system."

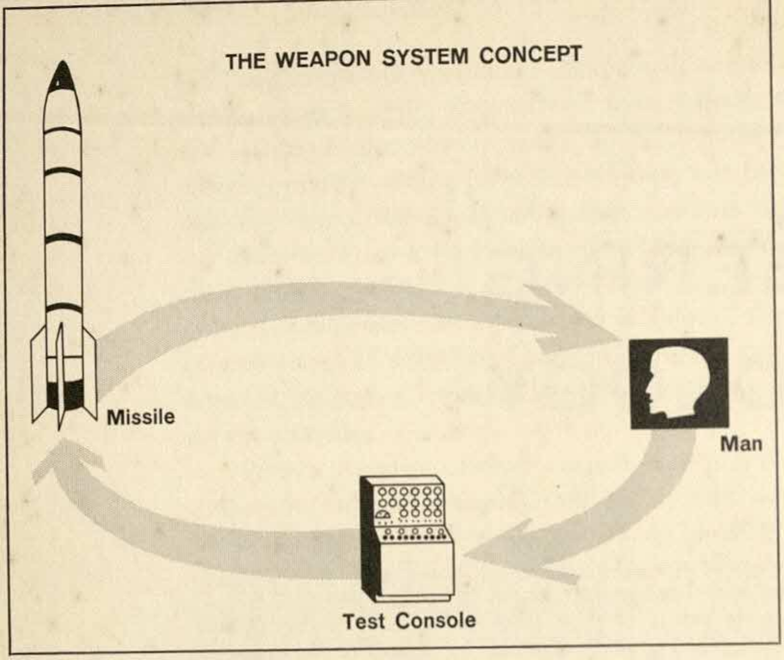


FIGURE 14.1. *A conception of a weapon system as a man-machine system.*

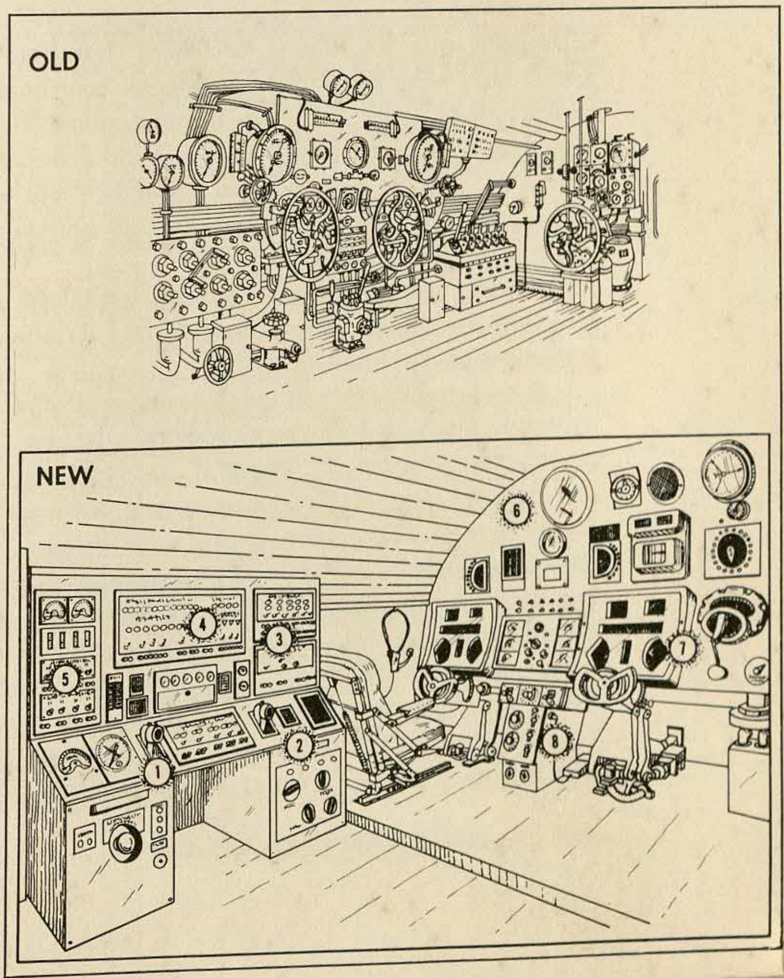
MAN-MACHINE SYSTEMS

Modern weapon systems are thought of by the United States armed forces as man-machine systems, in which the human operator is one major subsystem. A strategic missile system, for example, may be depicted as in Figure 14.1. In preparation for firing, the human operator sets certain signals into various units of ground support equipment which are transmitted to the components housed in the missile frame. These signals have the purpose of "questioning" the internal circuits and mechanisms to determine whether they are functioning properly. Signals that constitute the answers to these queries are transmitted back to the panels of ground support equipment, where they are observed and interpreted by man. After firing, if the missile is a guided one, the operator may insert other kinds of signals which control the missile's flight, and the reaction of the missile to these signals may again be transmitted to a panel, there to be observed by the human being. In both these instances, the critical role played by the operator is apparent: what the missile does at any given moment is reported to the man, and this in turn leads to actions by the man which control what the missile does in a subsequent moment.

The concept of the man-machine system is not confined to military weapons. Any set of operations has this same basic structure. A dial telephone system, for example, displays the same essential kind of interactions, although in this case there are two human operators. Operator No. 1 inserts signals into one set of equipment by dialing a number; these signals are transformed into a second kind of signal, a ring, which causes the second operator to react to the equipment on his end by picking up the phone. At this point the circular interaction of Operator 1⟶ equipment⟶ Operator 2⟶ equipment is complete and remains so until the conversation is over with.

Today the U. S. Postal Service is revising its man-machine system of processing mail. Until lately many functions have been assigned to men although machines are more suitable. On the other hand, man is better suited for certain functions than any machine yet developed. The proper design and linkage of man and machine functions is currently a subject of considerable study. Figure 14.2 shows the control center of a new submarine which makes use of many of the principles we shall describe in this chapter. This figure contrasts the new control center with a traditional

FIGURE 14.2. *An "old" submarine control center, and a "new" one which has been designed in accordance with human engineering principles.*



control center. While there are definite esthetic differences, the prime consideration is a better integration of man and equipment designed to yield improved performance of the entire system.

Man as a Component in a System

In this chapter we shall look at man as a component link in such systems. An electronic tube may be considered a vital link in a computer system, or a specific type of gear may be a critical link in a mechanical system. Similarly man frequently has an equally essential part to play in a total man-machine system. For optimum functioning of the entire system the components should be (a) suited to their functions, and (b) linked up in the best possible arrangement.

Basically man can serve as an important link in several components of a system. For one thing, he may be a *receiver.* In order to run a machine, a human operator must get information from it. Such information may come to him through any of the senses: through vision (as with lights and dials), hearing (as with tones or whistles), the pressure sense (as in vibrations), or others.

Man can also serve as an *evaluator,* and here his performance is especially good relative to that of machines. Thus, from the intermittent information on a radar display he can estimate courses and velocities of targets and determine times and points of interception. He is able to make decisions based on stored models of visual and auditory inputs. For example, he can identify an auditory sonar signal as a whale, a school of fish, or a submarine. Man can solve problems whose solution depends on novel combinations of stored concepts.

Finally, man can serve as a *controller* link in a system. He can talk, push buttons, point, operate controls, and do other things which initiate further action in the system.

A man-machine system may be composed of many men and machines, as is true in an air-traffic control tower, a bomber aircraft, or a television studio control center. Or a system may be made up of a single machine and a single man. Typical one-man and one-machine systems are represented by operating a lathe, driving a car, or operating an electronic tabulator. In all these examples of man-machine systems, regardless of their number of components, a particular man reacts to stimuli arising from some kind of machine *display;* he makes certain decisions, and carries out certain responses affecting the *controls* of the machine. These actions in turn cause the machine to furnish him with a new set of stimuli. Such systems, in which there is continuous interaction and "feedback" between man and machine, are called *closed-loop* systems. However, man may also be used as a component of an *open-loop* system, in which the "feedback" from the machine is remote or intermittent. This may happen, for example, in a communication system in which a man transmits a message, but has no way of knowing the immediate results of this transmission.

It is clear that many varieties of operations involving human activity may be viewed as interactions between man and machine. How can the engineering psychologist improve the effectiveness of these man-machine interactions? What are the implications of a knowledge of human abilities and skills for the design of new operations?

The human performances required in man-machine interactions have two kinds of implications for the design of systems:

1. The equipment may be designed to fit what is known about the performance capabilities of man.
2. In a larger sense, the total job, conceived as a set of operations involving man-machine interaction, may be designed to make efficient use of the functions of both man and machine. This point of view requires consideration of the factors which enter into the "design" of the man, including the provision of adequate job descriptions, selection in terms of relevant abilities, employing efficient training, and measuring human performance.

We shall first discuss the implications of knowledge about human performance for the first of these problems, the design of equipment to fit the man. Later on, we shall proceed to the more comprehensive problem of system design.

HUMAN BEHAVIOR AND EQUIPMENT DESIGN

In what ways can knowledge about human performance be applied to the design of equipment in a man-machine system? We shall see that the answer requires the use of knowledge from virtually all areas covered in this book. Basically, there are two types of considerations in designing equipment for human use. First, the equipment must be designed within the *limitations of human capacities.* It should not, for example, display signals which cannot be seen or heard, nor should it require control movements which cannot be made. The second consideration is the principle of *job simplification.* By this is meant that the designer must aim to make the equipment easier to operate, with less training, fewer human errors, and greater reliability.

We shall first describe some equipment design problems that require consideration of the limitations in human capacities. Then we shall take a closer look at some principles of job simplification, with examples of their application in equipment design.

DESIGN PROBLEMS RELATED TO HUMAN LIMITATIONS

Sensory Capacities

When man acts as a "receiver" in a system the *threshold limits* of his sense organs (both absolute and differential) must not be exceeded if the system is to work. As we learned in Chapter 7, the limits of human capacity in vision and hearing have been extensively measured, those for the other senses somewhat less so. All in all, a great many facts are known about human discrimination abilities and their limitations. Consequently, it is not usually difficult for the design engineer to locate any particular set of facts, and to employ them in such a way that the task being structured does not exceed human capacities. Here we shall examine some specific problems which have been encountered in equipment design.

Hearing and Noise. Systems for signalling or for voice communication must often be designed to function in the presence of noise. This is true, for example, in many types of industrial operations, in airplanes, in the engine rooms of ships, and on the decks of aircraft carriers. The intensity of human speech sounds must be far above the threshold of hearing to be effective in such environments. This is because of the phenomenon of *masking*, described in Chapter 7. The results shown in Figure 14.3 illustrate the masking of speech sounds by "white noise," a continuous spectrum of frequencies throughout the range used in speech. Beginning when the noise is 40 db above the standard reference, the intensity of speech sounds must be increased in constant proportion to that of the noise for the speech to be intelligible. As the figure indicates, the relationship is the same when

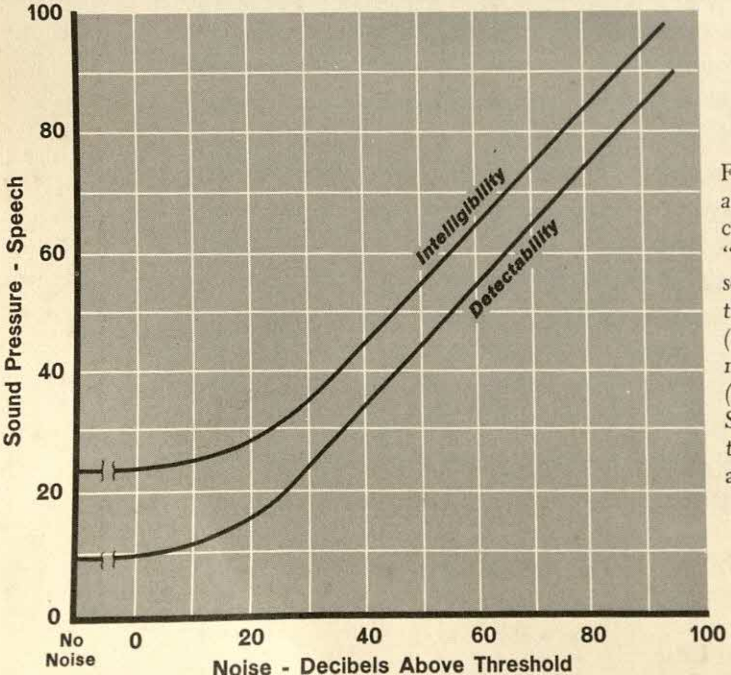


Figure 14.3. *Thresholds of detectability and intelligibility of speech communication in the presence of "white" noise. Intensity of speech sounds is plotted in decibels above the standard reference intensity (0.0002 dyne/cm²), intensity of noise in decibels above threshold. (After Hawkins, J. E., Jr., and Stevens, S. S., The masking of pure tones and of speech by noise, J. acoust. Soc. Amer., 1940, 22, 6-13)*

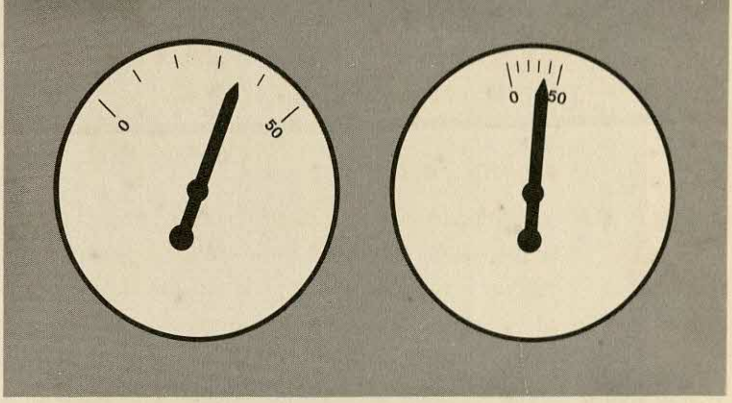


FIGURE 14.4. *Instrument dials used in a study to determine the effect of spacing between scale markings on accuracy of dial-reading. (From Grether, W. F., and Williams, A. C., Jr., Speed and accuracy of dial reading as a function of dial diameter and angular spacing of scale divisions. In Fitts, P. M. (Ed.),* Psychological research on equipment design. *Washington, D.C.: U. S. Govt. Printing Office, 1947)*

detectability of speech sounds, rather than intelligibility, is measured. The relation of speech intensity to noise intensity is often called the *speech-to-noise ratio* or *S/N ratio.* As the graph indicates, for most noises encountered in practical situations, the S/N ratio should be greater than −6 db in order for speech to be intelligible; in other words, the intensity of the speech can be less than that of the noise, but not more than 6 db less, in order to be intelligible.

Thus the designer of a system which produces noise would need to provide for amplification of voice communication delivered by means of a headphone or speaker, for such speech to be understood. He would specifically need to provide for an S/N ratio of −6 db or better.

LEGIBILITY OF LETTERS AND INSTRUMENTS. The capacity for visual acuity (see Chapter 7) naturally becomes involved in the reading of lettered signs and instruments. Consequently, equipment design must take into consideration the limitation of this human capacity.

A number of studies have been carried out to determine the effects of variation in the spacing between marks on aircraft instrument dials and the observer's accuracy in reading these scales to the nearest unit. Two instrument dials specially prepared for such a study are shown in Figure 14.4. In this study, numeral markings and the width of the scale markings were kept constant; only the distance between the scale markings was varied. In different observations, dials of diameters 1 inch, 1⅞ inches, 2¾ inches, and 4 inches were used, in order to test the effect of this variable. The observers were required to report readings to the nearest unit; in other words, they reported an interpolated value of the instrument reading.

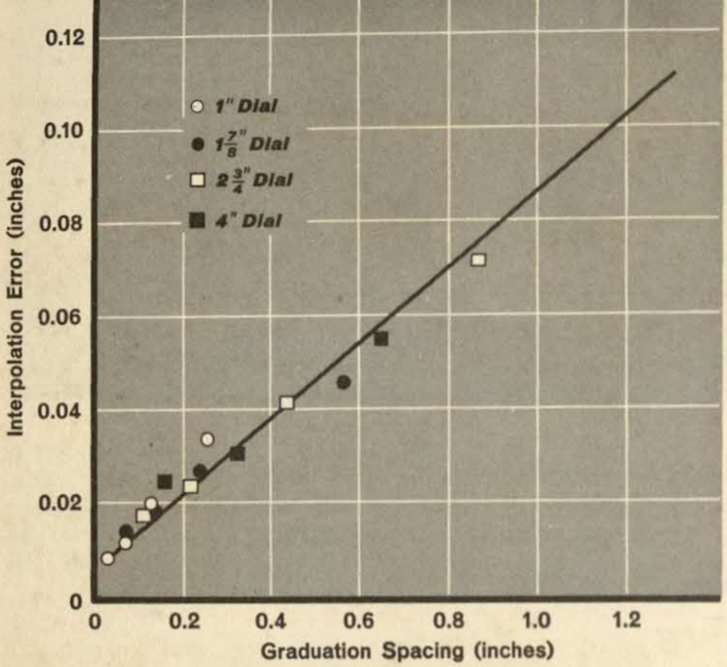


FIGURE 14.5. *Absolute amount of error (inches) in reading dials with various spacing intervals between graduations. Absolute error is shown to increase with larger spacings. (Data from Grether, W. F., and Williams, A. C., Jr., Speed and accuracy of dial reading as a function of dial diameter and angular spacing of scale divisions. In Fitts, P. M. (Ed.), Psychological research on equipment design. Washington, D.C.: U. S. Govt. Printing Office, 1947)*

The results obtained in this study are shown in Figure 14.5, where the absolute size of the error in reading the dials is related to the size of the graduation interval. As the figure indicates, absolute accuracy increases as the scale marks are placed closer together. The limits of visual acuity are not reached, apparently, as this and other studies have shown, until the distance between marks is decreased to about 0.05 inch, at a viewing distance of 28 inches.

A related problem involves the design of letters and numerals for optimal legibility, whether these appear on a printed page or on an equipment display panel. Several investigations have shown that a stroke that is rather narrow relative to the white spaces of letters or numerals is by far the best. One example, based upon a careful study of the legibility of numerals, is shown in Figure 14.6. Various investigations of the problem have resulted in recommendations for the ratio of width-of-stroke to width-of-letter from 12 to 25 percent; for width-of-stroke to height-of-letter, 8 to 17 percent.

When white-on-black numerals are to be displayed, even narrower strokes should be used for best legibility. This is indicated by the data

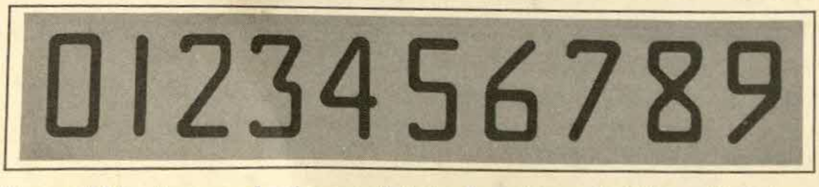


FIGURE 14.6. *An example of numeral design for optimum legibility. (Data from Berger, C., Stroke-width, form and horizontal spacing of numerals as determinants of the threshold of recognition: I., J. appl. Psychol., 1944, 28, 208-231)*

shown in Figure 14.7, where the white-on-black numerals with strokes of narrow width (6 mm, representing 7.7 percent of numeral height) yielded maximum legibility. For black-on-white numerals, best visibility, although less than white-on-black, was obtained with strokes of 10 mm, representing 12.5 percent of their height.

These examples show that it is often necessary to make specific determinations of human sensory capacities when particular applications in equipment design are required. This is also true for other human capacities. It is usually found that design requirements can be met readily so long as the designer stays within certain limits. For example, as Figure 14.7 shows, black-on-white numerals of 10 mm stroke width and 80 mm height can be readily seen at any distance up to about 33 meters. If the designer exceeds this distance limit, his system will not operate. If he must exceed it, then he must use larger numerals. Often, just a few observations using a human observer will suffice to determine that a given design is within human capacity limits. But sometimes it may be necessary to make more extended observations under the special conditions imposed by the equipment being designed.

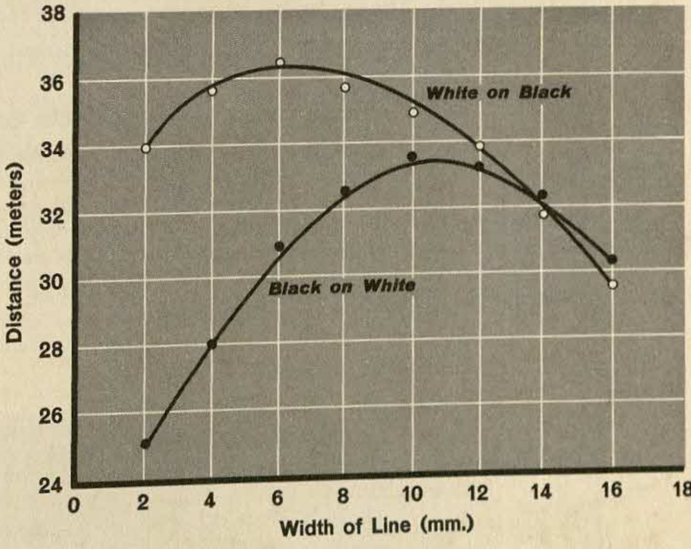


FIGURE 14.7. *Distances at which two observers could read numerals of varying stroke widths. The farther away these could be read, the better their legibility. Data are shown for both white-on-black and black-on-white numerals. (Data from Berger, C., Stroke-width, form and horizontal spacing of numerals as determinants of the threshold of recognition: I.,* J. appl. Psychol., *1944, 28, 208-231)*

Motor Capacities

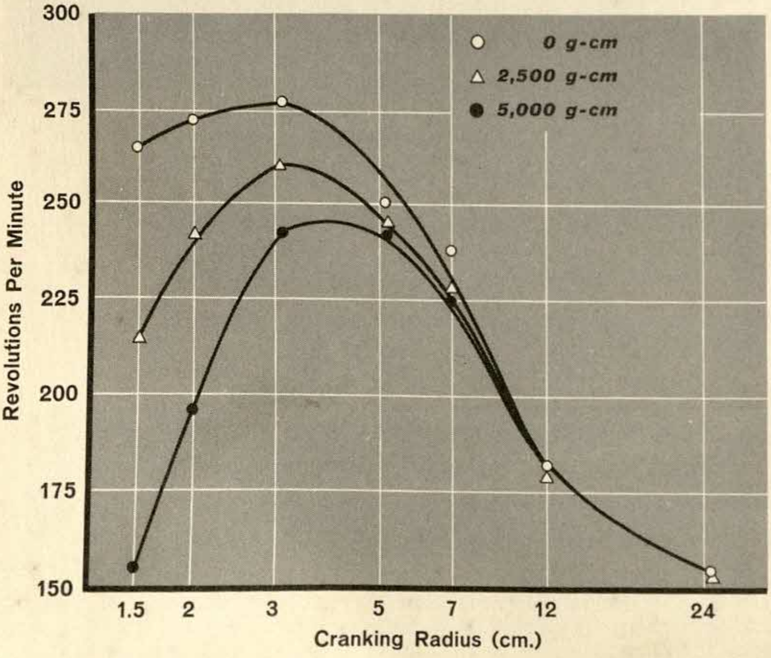
When a system requires a man to manipulate controls, the demands on the *motor response mechanism* must be within limits with respect to speed, force, and precision. Some of the important basic information on motor capacities has been described in Chapter 8. Here we shall give an example of an equipment design problem in which these capacities play a part.

SPEED OF HANDWHEEL-TURNING. Suppose a design engineer has to specify a handwheel or crank to be turned at a rather high rate of speed in the operation of equipment. How fast can such a handwheel be turned? Can a human being produce more revolutions per minute with handwheels of small diameter, or of large diameter? Does the *force* of turning make a difference?

In one study, the crank handle was mounted at about shoulder height for rotation in a horizontal plane. The measurements of rotation capacity for one individual, using the preferred hand, are plotted in Figure 14.8. With no load (friction, measured in gram-centimeters) on the crank, the highest RPM is attained with a radius of rotation of 3 centimeters. The speed attained with a handweel of this size would be about 275 RPM. As the radius is increased, speed of rotation drops markedly to about 150 RPM with a 24 cm radius. Cranking speed also decreases with increased friction. For maximum speed at any load, a handwheel of about 3 cm radius would be best. These results, of course, apply to the preferred hand; if the other hand is used, the results of this study indicate considerably lower cranking speeds.

Many specific design conclusions can be drawn from these findings. Notice, for example, that if we have a crank with a 3 cm radius, increasing

FIGURE 14.8. *Human capacity for crank rotation in the horizontal plane with cranks of different radii, and at three different torques. Data are for one individual, using his preferred hand. (After Reed, J. D., Factors influencing rotary performance, J. Psychol., 1949, 28, 65-92)*



the friction makes quite a difference in the speed of human motor performance. But if our crank is 12 cm or more in radius, friction makes no difference in cranking speed, at least up to a value of 5,000 gm-cm.

Similar applications of data on human limitations can be and often are used in equipment design. As indicated in Chapter 8, the force, speed, and precision of human motor capacities have been measured for various body members and for various directions and extent of movement.

Physical Dimensions

The dimensions of the human body and its members are also important for system design. The human operator must be able to fit in enclosed places; he must be able to reach controls to be operated; he must be able to direct his sense organs (particularly his eyes) toward the signals provided by equipment.

Some basic dimensions of human males, measured in aviation cadets during World War II, are given in Table 14.1. These measurements are for a large group of young men, and the extremes are not well reflected in the ranges given, since certain individuals who exceeded maxima and minima were not accepted for service. However, the average values probably are not significantly in error.

In an absolute sense, there is quite a range of values for each dimension given. Design must take these measurements carefully into account; it is

TABLE 14.1

BODY MEASUREMENTS OF YOUNG MALE ADULTS, IN INCHES

Dimensions	*Average*	*Range*
Standing height	69.20	61.4–78.0
Sitting height	36.40	32.7–40.6
Buttock-knee	23.60	19.3–27.6
Knee–sole of foot	22.00	18.1–25.6
Shoulder breadth	18.00	15.4–20.5
Chest circumference (rest)	35.70	30.7–43.3
Width across hip bones	11.40	9.1–13.4
Buttocks, lateral diameter (standing)	14.02	11.8–18.5
Arm reach (measured from back)	35.20	29.5–40.6
Chest depth	8.20	6.3–11.0
Foot length	10.50	8.8–12.2
Head length	7.78	6.8– 8.7
Head breadth	6.06	5.5– 6.8

(Data from Randall, F. E., Damon, A., Benton, R. S., and Patt, D. I., *Human body size in military aircraft and personal equipment.* USAF Air Materiel Command Technical Report 5501, June 1946.)

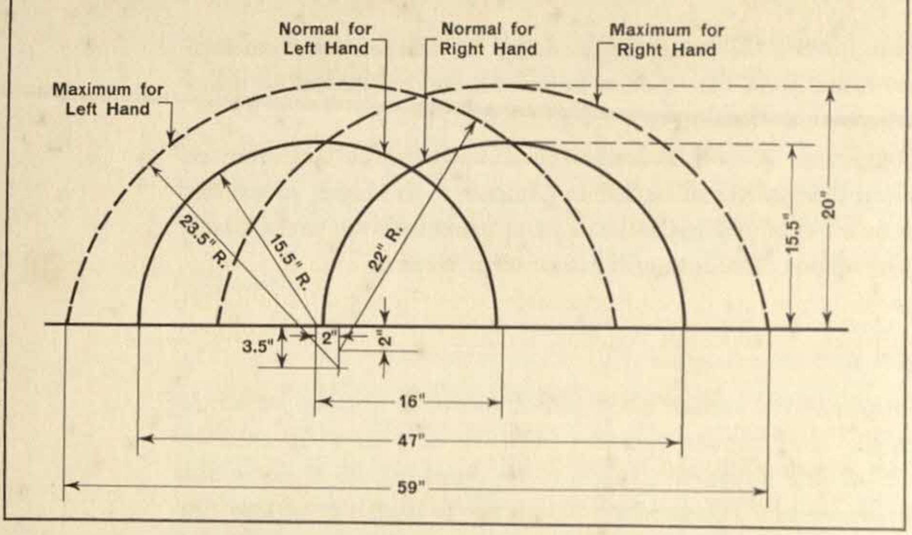


FIGURE 14.9. *Normal and maximum working areas on a horizontal surface. The measurements shown are not for average individuals; rather they include a range of about 95 percent of adults. (From Barnes, R. M.,* Motion and time study *(3rd Ed.). New York: Wiley, 1949)*

not sufficient to design for the "average" man. Wherever critical demands for space are made, as in aircraft and manned space vehicles, the physical dimensions of the human operator assume great importance. In the design of protective clothing, these and other physical measurements must be taken into account.

Of somewhat greater psychological interest are the dynamic features of human movement, particularly of the limbs, which depend upon these physical dimensions. For example, a horizontal surface is used in many different jobs. What is the maximum effective reach for a man seated before materials or equipment placed on such a surface? A diagram of "normal" and "maximal" working areas is shown in Figure 14.9. *Maximum working areas* are those in which no shoulder or trunk movements are required; in other words, they provide the limits of comfortable work. The area that can be reached with movements of only the forearm and wrist, which is to be preferred for continuous work over long periods of time, is called the *normal* working area. The area for each hand has the shape of a semicircle.

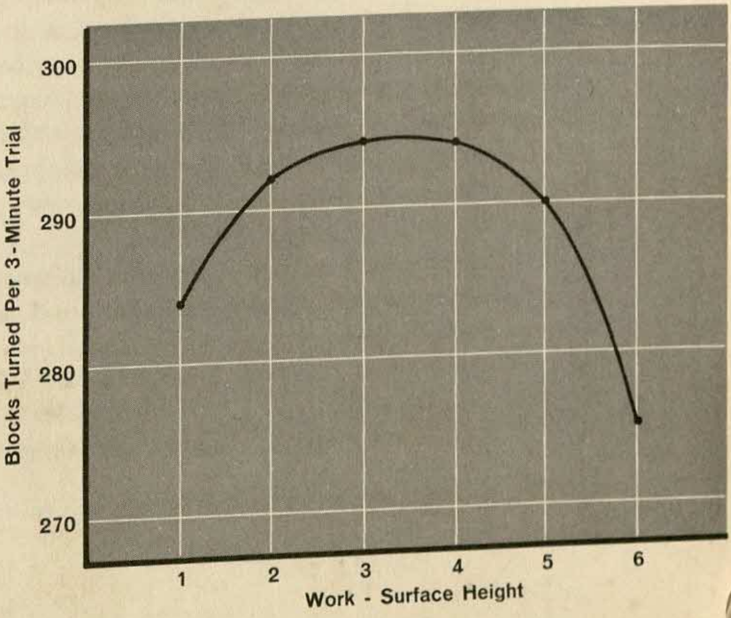
Other findings of interest to designers pertain to the optimum height of a horizontal working surface. In one study, individuals were given the task of turning over wooden blocks and reinserting them into holes in a rectangular board (a modification of the Minnesota Rate of Manipulation Test of manual dexterity). The number of blocks turned during six 3-minute trials separated by 2-minute rest periods was measured on each of two days. Each individual performed the task at six different work-surface heights, varying from about 19 inches below elbow height to 8 inches above. The results are illustrated in Figure 14.10.

Significant variations in performance were found at each work-surface height. This was true during early stages of learning, on Day 1, as well as during later stages on Day 2. The best height appears to be between 3 and 8 inches below the elbow. The reason for superior performance at this work-surface height is probably one of reduced muscular tension; the individuals taking part in this study reported reduced feelings of muscular strain at heights 3 and 4.

Capacities for Decision-Making and Learning

The human capacity for *decision-making* needs to be considered in equipment design. As we saw in Chapter 3, the limits of this capacity are not precisely known. For one thing, the decisions required of operators in man-machine systems vary widely in complexity. In some circumstances, the decisions are predetermined for the operator in the sense that a particular stimulus calls for a particular decision and response. In other circumstances the operator has no standardized set of instructions, but must select

FIGURE 14.10. *Performance curves expressing the relation between number of blocks turned and height of work surface. Work-surface height was determined precisely in relation to distance of each individual's hand from the floor. However, the following average values of distance above or below the elbow can best be used to define this height: 1 = −18.9 in.; 2 = −13.5 in.; 3 = −8.2 in.; 4 = −2.8 in.; 5 = +2.6 in.; 6 = +7.9 in. (Data from Ellis, D. S., Speed of manipulative performance as a function of work-surface height,* J. appl. Psychol., *1951, 35, 289-296)*



and use his stored concepts as a basis for making judgments. A good example of the latter situation occurs in the job of the control tower operator. The design of such a system presents the persistent problem of assigning the traffic load to each operator in such a way that his decision-making performance does not deteriorate as the load grows heavy.

Basically, tasks which require decision-making may exceed human limitations when they present too great a number of alternative concepts simultaneously. We saw in Chapter 8 (Figure 8.5) that decision time for standard motor reactions increases logarithmically with an increase in the number of alternate choices. Even in complex situations there is an advantage in time saving, and in reduced likelihood of error, when the number of alternative choices available is kept limited. Besides being able to choose from known alternatives, man can perform many complex decision-making functions better than any machine developed. He is especially good at recalling generalized patterns of previous experience in order to solve immediate problems. In other words, he can solve problems by choosing among hypotheses, in the manner described in Chapter 9.

Design of equipment must also take into account limitations in the human being's *capacity for learning*. There is clearly some limit to the degree of complexity of a model to be learned, or to the number and length of verbal sequences which can be retained at any one time, or to the variety or richness of retained concepts which can be brought to bear on a given problem. However, the upper limits of such capacities are seldom if ever even approached in human activities. Although instances of exceeding learning capacity may be conceived in equipment design, this seldom happens.

The importance of *learning* and *transfer of training* for design of man-machine operations lies mainly in the fact that correct planning can achieve an assignment of function to man and machine which cuts training time to a minimum. The machine can be designed to do what it can best do, and the man can be "designed" to do what he can best do, with least over-all cost. This means that a man can be assigned functions in the system which take advantage of the abilities he brings with him or the skills he can acquire by learning and transfer in the shortest possible time.

JOB SIMPLIFICATION IN DESIGN OF EQUIPMENT

Job simplification is of great importance for *placement* of men in jobs. The tasks of these jobs may require human abilities which support the learning of motor skills, verbal sequences, models and scales, or concepts.

Simplification can have significant effects in reducing the level of abilities required of men who are to fill jobs created by the development of man-machine systems. This has the effect of conserving manpower, since the higher the ability levels required in a job, the scarcer is the supply of qualified people. In addition, simplifying jobs by proper equipment design *reduces the training* required. As an example, suppose a machine can be designed to require only four steps in a sequence for its operation, as opposed to twenty-four steps. We can recognize immediately that the aptitude for learning and retaining a 4-step sequence within a given time limit represents a level of ability possessed by a far greater proportion of the population than ability for learning a 24-step sequence in the same time limit. From another point of view, whatever the initial ability requirements, the time required for training the selected individual in the 4-step sequence will be considerably shorter than for training a 24-step sequence.

Alternative Approaches to Job Simplification

There are several ways in which job simplification may be achieved for a particular piece of equipment.

SIMPLIFICATION BY CHANGING THE ABILITY REQUIREMENTS. We can illustrate this type of simplification by one of the more dramatic changes in a job in the textile industry. The original hand loom for weaving cloth utilized a somewhat complex motor skill which took many months to learn. When this loom was replaced many years ago by one in which the shuttle and beater were mechanically operated, the need for training in this particular skill disappeared, thus shortening the total time needed to train a skilled weaver. Later still other tasks were eliminated in the "automatic loom," and for these were substituted tasks requiring different abilities and skills, including that of searching for and recognizing sources of malfunctions when the mechanism stopped automatically. The total effect, however, was to greatly simplify the job to the extent that one operator could "tend" several looms at one time, instead of "operating" one. The use of new action verbs in the job description ("tend" instead of "operate") summarizes the significant effects of this job simplification.

A recent experiment demonstrated that the ability requirements of a task may be changed by certain simplifications in the stimulus-response relationships even with very little change in the basic mechanism of the equipment. Figure 14.11 shows the basic task studied. In response to a stimulus light on the display panel, the operator must push a corresponding button on the response panel as rapidly as possible. The experiment studied the effect of rotating the display panel on both the difficulty of the task and the abilities required for effective performance. Figure 14.11

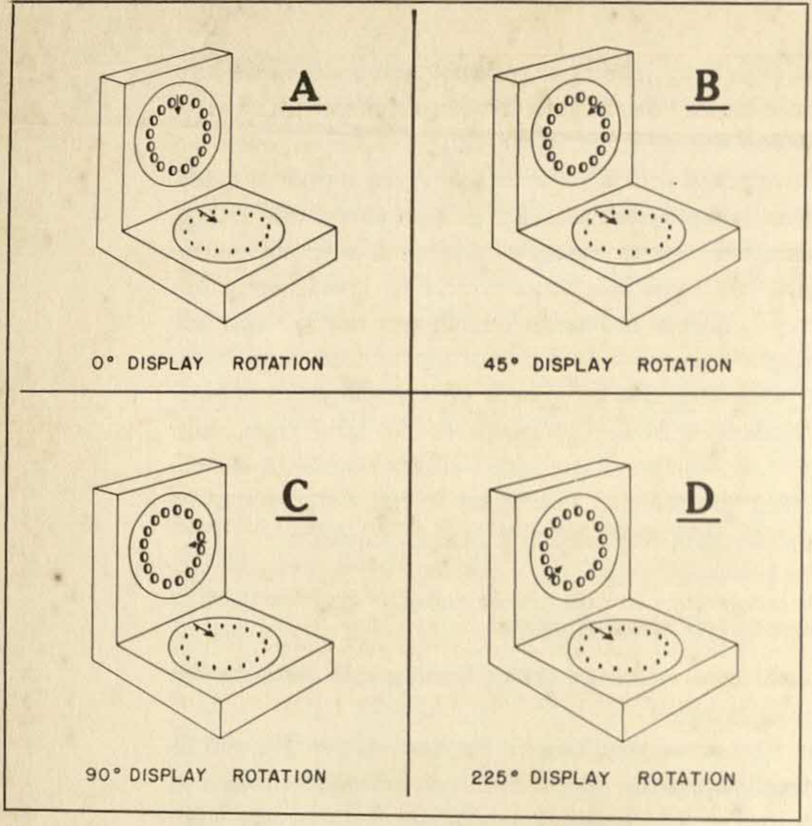


FIGURE 14.11. *Device used to study the effects of varying task difficulty on the abilities required. The task requires the operator to push the button which is the same angular distance from its arrow as is a lighted bulb on the upright panel from its arrow. Four of the eight task conditions are shown. (From Fleishman, E. A., Factor structure in relation to task difficulty in psychomotor performance,* Educ. and psychol. Meas., *1957, 17, 522-533)*

shows four of the eight degrees of rotation used. Since the 200 individuals who performed on this task also received a battery of separate ability tests, it was possible through correlational techniques to determine the abilities contributing to performance in each task variation.

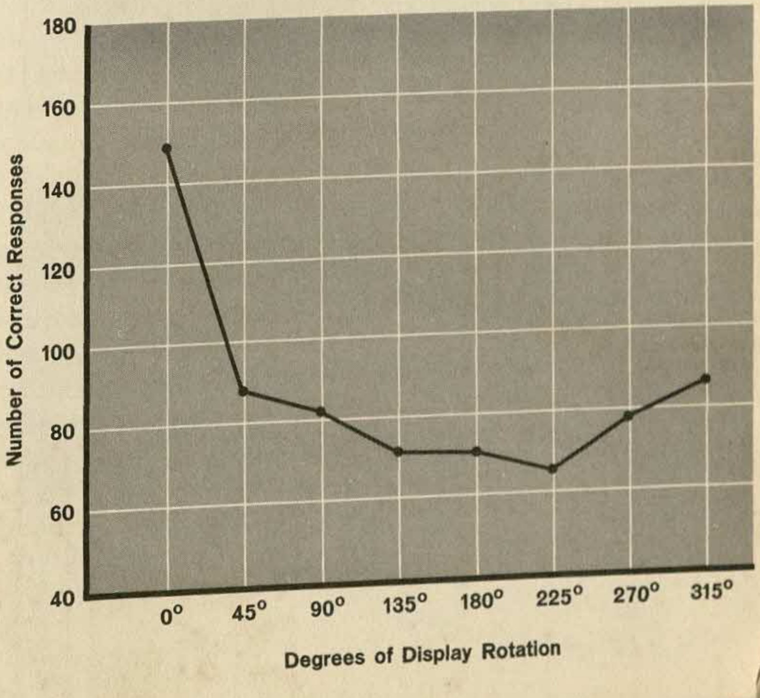
Figure 14.12 shows that different degrees of display rotation did produce markedly different degrees of difficulty in the task. The task was "simplified" the closer the display arrow was kept near the top of the panel. Table 14.2 lists the different abilities which were required as the degree of display rotation was changed. The task was most highly simplified when there was a direct correspondence between stimulus and response positions, and in this case performance was largely supported by *perceptual speed ability*. As the task became more difficult, performance came to depend increasingly on *spatial orientation* and *response orientation* abilities. (The nature of these abilities has been described in Chapter 5.) By de-

TABLE 14.2
RELATIONSHIPS OF DISPLAY ROTATION TO ABILITIES REQUIRED

Display Rotation in Task	Ability Factor			
	Response Orientation	*Spatial Orientation*	*Perceptual Speed*	*Spatial Visualization*
0° (↑)	.08	.07	.47	.01
45° (↗)	.18	.34	.40	.00
90° (→)	.08	.69	.25	.04
135° (↘)	.37	.48	.05	−.05
180° (↓)	.40	.40	.04	.08
225° (↙)	.30	.35	.02	.04
270° (←)	.21	.30	.14	.19
315° (↖)	.25	.16	.36	.08

(After Fleishman, E.A., Factor structure in relation to task difficulty in psychomotor performance. *Educ. psychol. Measmt.,* 1957, *17,* 522-533) In this task, maximum rotation is 180°; further rotation moves the arrow around toward 0° again. Correlations are shown between four ability factors and the task of Figure 14.11, under different conditions of display rotation. The *response orientation* and *spatial orientation* abilities show increases in correlation as the display rotation departs from the upright position. *Perceptual speed,* in contrast, decreases the size of its relationships the farther the display is from the upright. *Spatial visualization* ability appears not to be involved in this performance under any task condition.

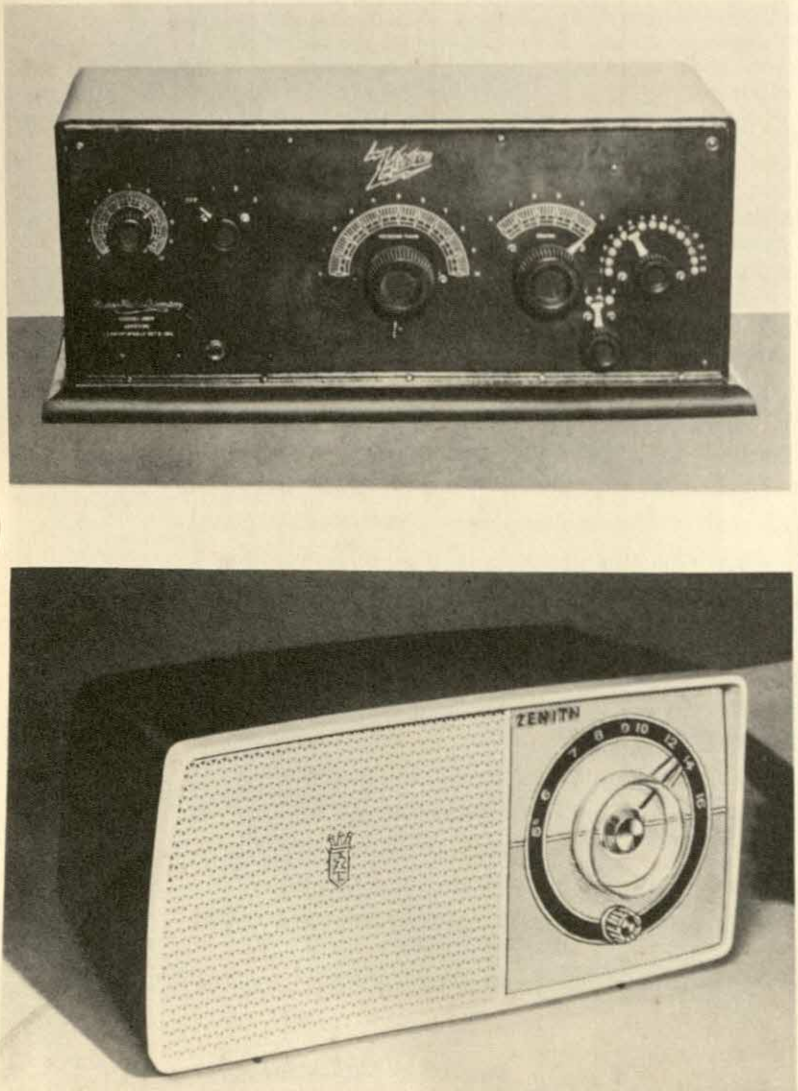
Figure 14.12. *Number of correct responses for each condition of display rotation, using the task of Figure 14.11. The most difficult positions were those in which the reference arrow pointed downward. As the display approached the upright position (0°), the task became easier. (After Fleishman, E. A., Factor structure in relation to task difficulty in psychomotor performance,* Educ. and psychol. Meas., *1957, 17, 522-533)*

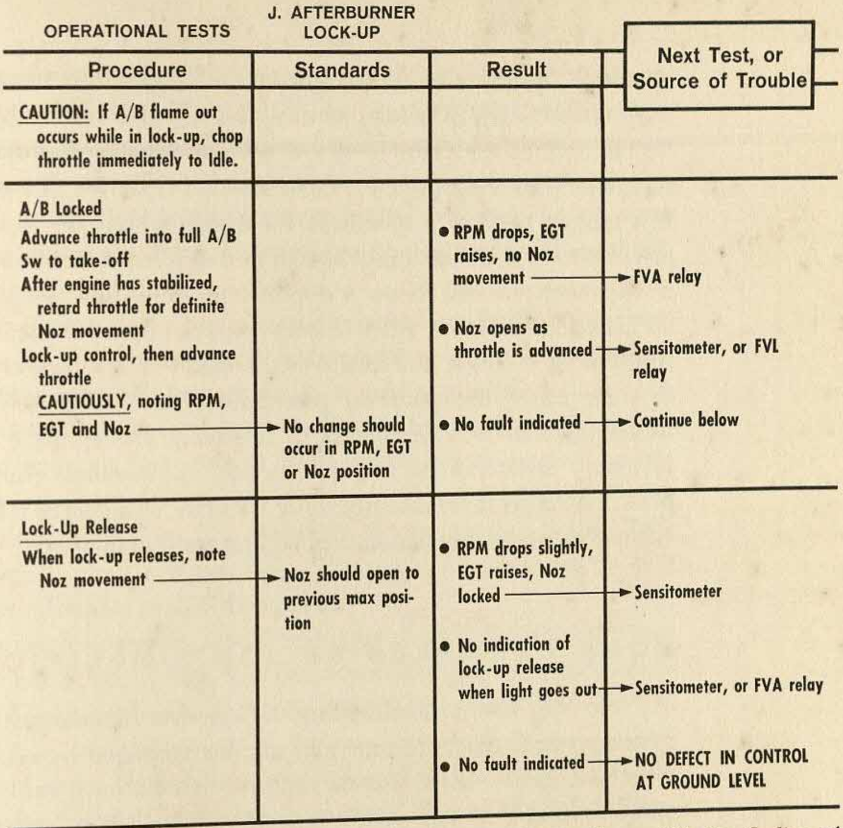


creasing the difficulty of task, the number of abilities critical to performance was reduced. As a consequence of such simplification, it would be easier to find people who could achieve high proficiency on the task.

Reducing Length and Complexity of Tasks. A simple and homely example of job simplification of this sort may be found in the radio receiver for home use. Following the crystal set era, home radios were contained in large boxes having many knobs, switches, and dials on their front panels. A typical superheterodyne receiver might require a 15-step sequence for turning on and tuning in a station. The operator of such a set had to practice this procedure at least a dozen times before he was good at it. The

Figure 14.13. *Job simplification by reduction of length and complexity of task, seen in a 1923 radio receiver and a 1958 radio receiver. The number of steps required to turn on the receiver and tune in a station has been reduced in the latter set to three, executed with two knobs. (Courtesy Zenith Radio Corporation)*





OPERATIONAL TESTS

J. AFTERBURNER LOCK-UP

Procedure	Standards	Result	Next Test, or Source of Trouble
CAUTION: If A/B flame out occurs while in lock-up, chop throttle immediately to Idle.			
A/B Locked Advance throttle into full A/B Sw to take-off After engine has stabilized, retard throttle for definite Noz movement Lock-up control, then advance throttle CAUTIOUSLY, noting RPM, EGT and Noz →	→ No change should occur in RPM, EGT or Noz position	• RPM drops, EGT raises, no Noz movement → • Noz opens as throttle is advanced → • No fault indicated →	→ FVA relay → Sensitometer, or FVL relay → Continue below
Lock-Up Release When lock-up releases, note Noz movement →	→ Noz should open to previous max position	• RPM drops slightly, EGT raises, Noz locked → • No indication of lock-up release when light goes out → • No fault indicated →	→ Sensitometer → Sensitometer, or FVA relay → NO DEFECT IN CONTROL AT GROUND LEVEL

FIGURE 14.14. *Sample page of a handbook designed to make possible the finding of malfunctions in the electronic fuel-control system of an aircraft by following a step-by-step procedure.*

sequence was not only long, but the tendency to internal interference (knob 2 might be quite similar to knob 7) made it complex. Ingenuity soon reduced this sequence to one or two steps, or three at the most, involving a power-on switch, a volume control, and a station selector. Thus the need for practice in this procedure was almost completely eliminated; it could be learned in one trial. Familiar as this example is, it should be realized that scores of types of jobs generated by complex electronic equipment have been simplified in similar ways, and that such simplification has reduced the requirements for selection and training.

PROVIDING JOB AIDS. Simplification of tasks of the job may be undertaken by developing an auxiliary printed check list, manual, or list of instructions, rather than by altering the equipment itself. Typically, a job aid may reduce or eliminate the need to retain sequences, models and scales, or concepts. The human operator, rather than having to recall such items, finds them in a check list or handbook. A job aid may also make possible the substitution of one ability for another, as when a set of rules are reduced to specific procedures to be followed, changing the function required of the human being from one of using concepts to one of merely exercising simple habits. An example of a check list covering the diagnosing of malfunctioning in a complex electronic system is shown in Figure 14.14. This is a sample page of a handbook for a man whose job it is to maintain an electronically controlled fuel system in a modern combat airplane. By using it, the mechanic can follow a step-by-step procedure in checking a particular function, compare what he sees with the described standards, note the result of each check, and finally be directed to the source of the trouble (or, in some cases, to additional procedures which ultimately enable him to locate the source). Mechanics of relatively low aptitude levels and with relatively little training are able to find malfunctions using such a handbook. Without it, mechanics must be more stringently selected and more extensively trained in concepts of equipment functioning.

SOME EXAMPLES OF JOB SIMPLIFICATION

We turn now to some examples of human functioning in man-machine systems which illustrate how jobs can be simplified by taking into account what we know about human abilities. As we have said, the aim of job simplification is to reduce the stringency of selection and training required for operation and maintenance of equipment. In contrast to considerations of human capacity, which determine whether equipment can be operated at all, simplifying jobs has the effect of reducing delays and expense associated with selection and training for high levels of proficiency. This, however, is an extremely important goal, if we are to insure best use of the manpower available to our nation.

Habits

Some jobs require the learning of both a great number and a variety of simple habits such as those involved in turning switches, adjusting knobs, making dial settings, and so on. These habits sometimes form a part of sequences of activity, while sometimes they occur as isolated events which must be exhibited at various times. Habitual acts required in emergencies, for example, must be capable of being performed quickly, whatever sequence of job activities may be interrupted when the emergency occurs. While simple habits are easy for human beings to learn, the occurrence of a large number of them in a job creates a condition which can readily lead to habit interference, and thus to the occurrence of critical errors.

Some habits of reaction to equipment are easier to learn than others, particularly when they can be acquired by transfer from older, well-established habits. For example, certain directions of movement of the stimulus seem to "go naturally with" similar directions of response movement. Such S-R combinations are often spoken of as being "highly compatible." Several studies have been carried out to determine S-R compatibility.

In one such study, the stimuli were presented on panels like those shown in Figure 14.15. The appearance of a light in a particular position was to be associated with a movement in a comparable direction. The three response panels employed are also shown in Figure 14.15. The individual responded correctly by moving a metal stylus from the central button of the response panel in a direction comparable to the position of the stimulus light. Eight directions for movement of one hand were required in response panel R_A, four for panel R_B. For panel R_C, reactions in two directions were required for each of two hands.

Obviously, stimulus panel S_A should be highly compatible with response panel R_A, S_B with R_B, and S_C with R_C. But how about the compatibility of S_A and R_C? Would this set of simple habits be harder to learn than those of S_A–R_A? To test this, an experimental study was carried out using 72 young Air Force enlisted men, formed into nine groups matched for an initial measure of response speed (two-choice reaction time). Each of these groups was given 20 practice trials, followed by 40 test trials, on one of the nine combinations of stimulus panels and response panels. Each stimulus panel was paired with each response panel. Performance was measured in terms of time and also in errors (incorrect directions of response).

The results gave the more or less expected finding that some S–R combinations were significantly more compatible than others. In rank order, considering both time and errors, compatibility of the nine combinations was: S_B–R_B; S_A–R_A; S_B–R_A; S_A–R_B; S_C–R_C; S_A–R_C; S_C–R_A; S_B–R_C; S_C–R_B. For any given stimulus panel, the most compatible response panel was the one most familiar in its directional pattern.

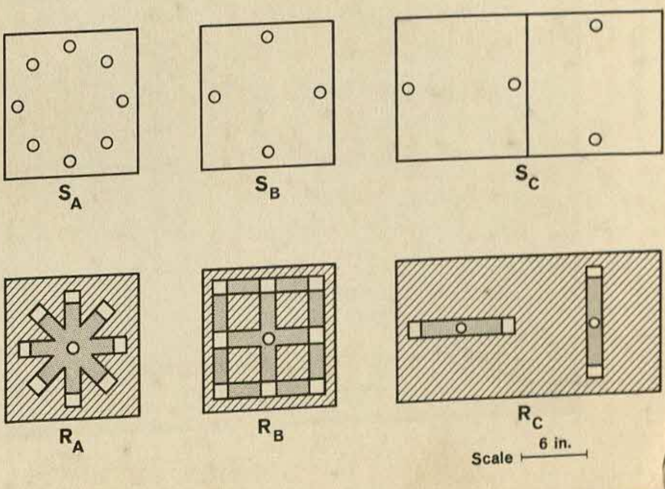


FIGURE 14.15. *Three stimulus panels (S_A, S_B, and S_C) and three response panels (R_A, R_B, and R_C) used in a study of S-R compatibility. Responses were begun with the metal stylus on the central button of the response panel. (From Fitts, P. M., and Seeger, C. M., S-R compatibility. Spatial characteristics of stimulus and response codes, J. exp. Psychol., 1953, 46, 199-210)*

A second study using these same panels demonstrated the great difference in ease of learning which exists between a combination like S_C–R_A and the high compatible combination S_A–R_A. Five college students were given extended practice in these tasks during a period of months, practicing the tasks for 16 trials each on any one day. The results are shown in Figure 14.16. It is evident from these results that the habit S_C–R_A starts at a much lower level of strength and takes considerably more time to learn than does S_A–R_A. If practice were continued, we should expect them ultimately to reach the same level. The reason for differences in compatibility, therefore, is doubtless to be sought in transfer of training from the previously learned habits of the individual. S_A–R_A is more "natural" and "compatible" than S_C–R_A because the individual has learned many habits which are like S_A–R_A. Thus a job can be simplified even in the simple habits it contains, by taking account of S–R compatibility. As we have seen previously (see Table 14.2), underlying ability requirements may also be changed by altering S–R relationships.

FIGURE 14.16. *Learning curves for five college students in the habits required by combinations of stimulus and response panels S_A-R_A and S_C-R_A. Performance is shown in terms of response time for 26 practice sessions, each consisting of 16 trials. (Data from Fitts, P. M., and Seeger, C. M., S-R compatibility. Spatial characteristics of stimulus and response codes, J. exp. Psychol., 1953, 46, 199-210)*

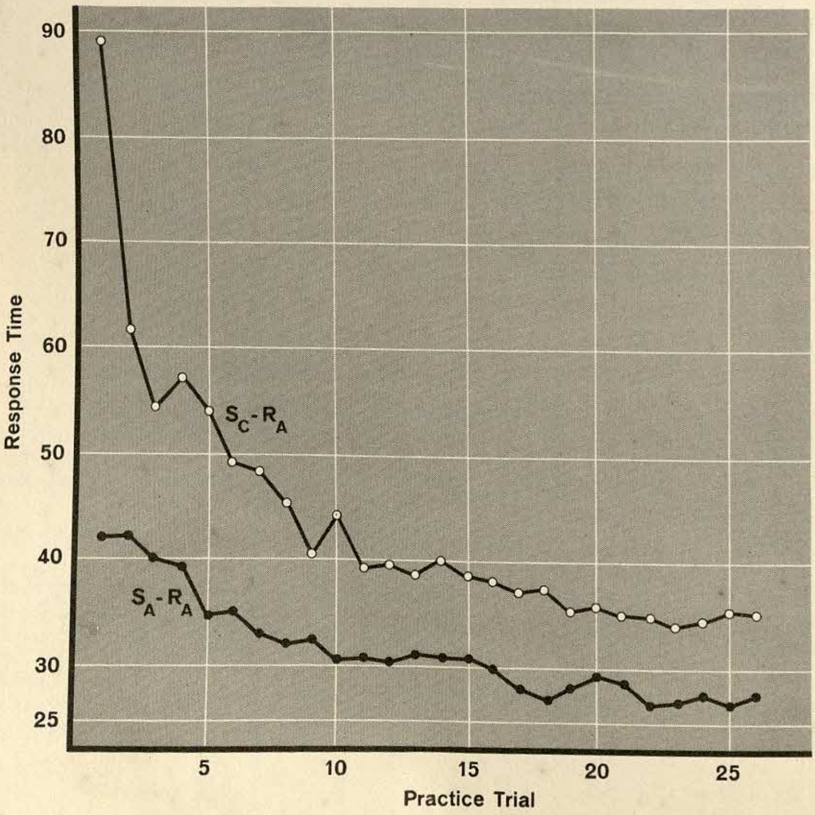
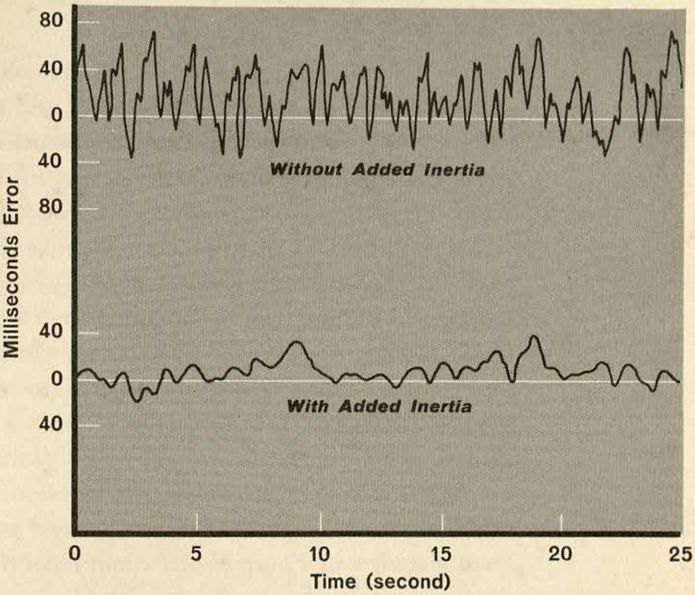


FIGURE 14.17. *Effect of added inertia in the tracking of an irregularly moving target with a light handwheel, shown in two tracking-error records. Amount of error is measured in milliseconds. (From Helson, H., and Hower, W. H.,* Inertia, friction, and diameter in handwheel tracking, *OSRD Report 3454, The Foxboro Company, 1934)*



Motor Skill

As we have already seen in Chapter 8, the learning of motor skills involves the acquisition of sequential connections between motor responses and stimuli that are partly external, partly internal. For continuous motor skills the precision of control by kinesthetic stimuli increases with practice and exhibits itself in a constantly increasing accuracy of performance.

If one aims to simplify this type of motor skill, various methods can be used to magnify the difference between successive kinesthetic stimuli, thus making easier the differentiation of incorrect and correct associations within each sequence. This magnification of kinesthetic stimulation can be done in a number of ways. One of the simplest ways is the introduction of inertia, or of friction which is proportional to the rate of movement (viscous friction). Using a control with inertial friction, the individual feels a greater resistance to motion the faster he moves the control.

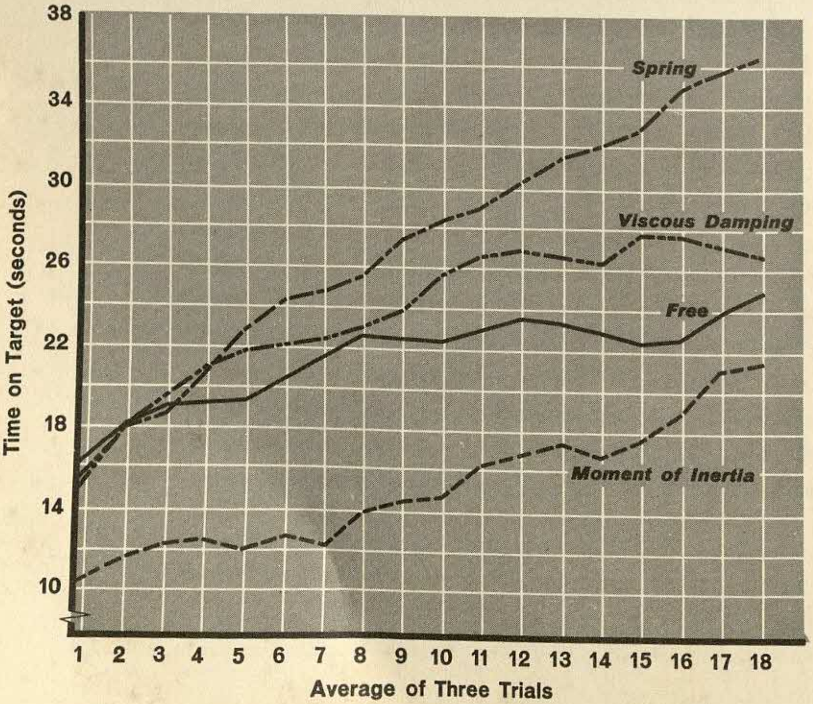
Figure 14.17 shows the effect of inertia on the task of following an irregularly moving target by movements of a light handwheel. Two different amounts of inertia were used. The two different tracking records show clearly the "smoothing" effect of added inertia, evidenced by a reduction of error time. Presumably, such smoothing results from the increased distinctiveness of kinesthetic cues provided by the added inertia.

A study of the effects on motor performance of three different types of kinesthetic feedback provides some important findings for job simplification pertaining to motor skills. The task in this study was one of keeping a moving spot centered on an oscilloscope screen by appropriate rotation of a control handle. (The moving spot actually moved in simple harmonic motion with a frequency of 15 cycles per minute and an amplitude of 4 inches.) The shaft of the control handle was fitted with three different mechanisms to magnify certain properties affecting the kinesthetic feedback. First, *positional feedback* was magnified by attaching a spring, so that spring tension increased regularly as the handle moved farther away from a central position. Second, *velocity feedback* was magnified by viscous damping, by energizing a magnetic field around a disc geared to the control handle, in such a way that a drag was produced on the control handle proportional to its velocity of angular movement. (This is equivalent to the viscous friction previously described.) Third, *acceleration feedback* was magnified by attaching arms and weights to the control shaft.

Which kinds of magnification, position, velocity, or acceleration, make this motor task easier, by providing more useful kinesthetic feedback? The results shown in Figure 14.18 come from a study in which 80 individuals practiced each type of task during 20 one-minute trials separated by one-minute rest periods. The graph shows the results obtained with single control factors only, although various combination were also tried.

Providing spring tension had a marked effect in speeding up the learn-

FIGURE 14.18. *Average time-on-target scores (15 percent of the total amplitude of target oscillation) for 80 individuals in the practice of a compensatory pursuit task. Each point represents a "running average" of three adjacent 1-minute trials. Four conditions of kinesthetic feedback are shown, identified by the physical constants applied to the shaft of the control handle. (After Howland, D., and Noble, M. E., The effect of physical constants of a control on tracking performance, J. exp. Psychol., 1953, 46, 353-360)*



ing of this motor tracking task. Thus the task was simplified (relative to the "free control" condition) by magnifying the *positional* aspect of kinesthetic feedback. Increasing the amount of velocity feedback also had the effect of improving the speed of learning. Accelerative feedback, on the other hand, had a depressing effect on the motor performance when it was magnified. For a motor task requiring this type of tracking, the design implications are clear: magnifying the position feedback by a spring or other means will make learning easier.

Models and Scales

Simplifying the job can also be accomplished, sometimes with quite striking results, for tasks that require the making of identifications by learning models and scales.

A comprehensive study of altimeter-reading provides an excellent example of findings of large differences among nine instrument designs in the ease of reading altitude. The nine designs compared in this study, using two different groups of individuals (college students, and experienced pilots), are pictured in Figure 14.19. The percentages of errors made in readings and the time required for interpretation of the dials are also shown for both groups, underneath each dial. (*See next page*).

Several interesting conclusions can be drawn from these findings:

1. Note that the most difficult dials to interpret were E and F. In E, two dials rotating behind a window indicate multiples of 1,000 ft. In F, the pointer makes one revolution to cover the entire altitude range. The range being covered is indicated in the window as 0–1,000 ft., 0–10,000 ft., or 0–100,000 ft. The fact that college students made fewer errors than pilots probably means that there is interference between the habits acquired for these scales and for those more familiar to pilots (like A). In any case, the scales to be acquired for E and F are rather difficult.

2. Instruments A and B are similar to those in use at the time the study was done. Their relatively great difficulty is indicated by the rather high percentage of errors made by both groups.

3. For instrument A, the most familiar to pilots, there is a considerable difference in performance between the pilot and college student groups. The pilots, of course, have had considerably greater amounts of practice with this scale.

4. Instrument D, which combines a direct-reading scale for thousands of feet with a circular scale for additional altitude, turns out to be a relatively simple scale, for both pilots and non-pilots. Learning of such a scale is apparently quite rapid.

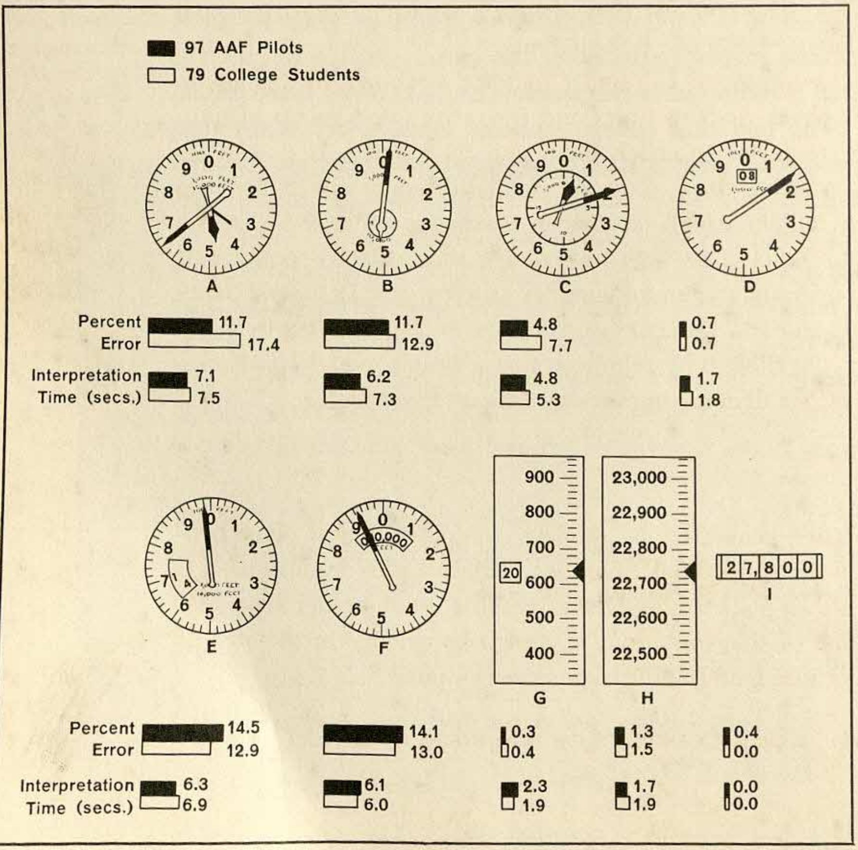
5. Vertical scales and direct-reading scales (G, H, and I) are relatively

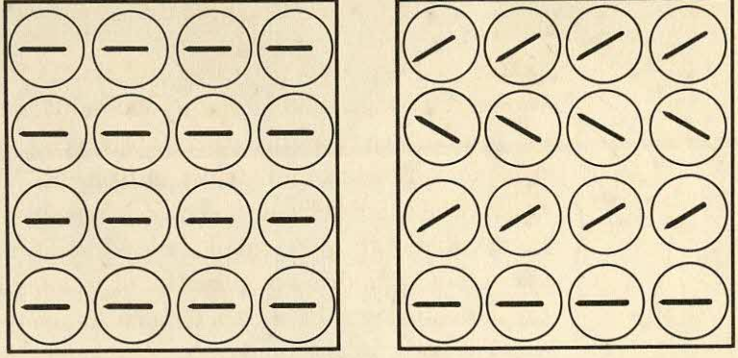
simple to learn. No particular differences in performance are found between experienced and inexperienced individuals.

Thus it is clear that there are several design possibilities to choose from for altimeters and similar instruments. Some require the learning of scales which are difficult and which remain difficult even after long practice. Others are quite simple, even for the naive person, presumably because they capitalize upon transfer of training from other scales with which the individual may have been familiar for many years.

PATTERNS OF INSTRUMENTS. Another example of job simplification involving identification of a model derives from a study of patterned displays of instruments. An airplane cockpit contains many instruments, and frequently groups of these instruments (such as those pertaining to engine functioning) have to be observed many times during a flight in order to note deviations from some prescribed readings. This performance is commonly referred to as "check-reading," to imply that the instruments are *checked* for indications of normal functioning, but not *read* for a precise value. Although

FIGURE 14.19. *Altimeter instrument designs used in a study of ease of interpretation of nine different instruments. Results show percent errors and interpretation time for a group of 97 pilots and a group of 79 college students. Bar graphs indicate percent error of 1,000 feet or more ("interpretation errors") and interpretation time in seconds. (From Grether, W. F., Instrument reading: I. The design of long-scale indicators for speed and accuracy of quantitative reading,* J. appl. Psychol., *1949,* 33, *363-372)*





0.75 - Seconds Per Reading - 1.64

12.8 - Percent Errors - 16.7

FIGURE 14.20. *Arrangements of groups of sixteen instruments into patterns which yielded short check-reading times and small percentages of error. The model required in each of these cases is quite simple, in contrast to that required in an irregular arrangement. (From White, W. J.,* The effect of dial diameter on ocular movements and speed and accuracy of check-reading groups of simulated engine instruments, *USAF Air Materiel Command Technical Report 5826, 1949)*

these instruments provide indications of different functions, their dials are nevertheless very similar in appearance.

In the typical airplane cockpit, the arrangement and orientation of these dials is not patterned. That is, the "normal" position of the pointer differs for each dial. The contrast between such an irregular pattern and those depicted in Figure 14.20 will be apparent.

When dials were arranged in regular patterns as shown in this figure, they yielded short check-reading times and few errors in a group of individuals who were required to check them and to respond as quickly as possible to any deviations they showed. As indicated in the figure, the simplest pattern of all, in which all sixteen needles were oriented in the same direction, was reacted to with an average time of 0.75 second and 12.8 percent errors. A slightly more complex pattern gave a time of reaction of 1.64 seconds and 16.7 percent errors. These arrangements provide an example of simplifying the job by requiring that a simple model (patterned dials) be learned rather than a complex one (unpatterned dials).

Concepts

The jobs that are generated by modern equipment often place considerable emphasis on conceptual functions. Those tasks requiring judgment or problem-solving are frequently assigned to man rather than machine, partly because of the limitations of design knowledge in the area of judgment, partly because man is an "inexpensive computer."

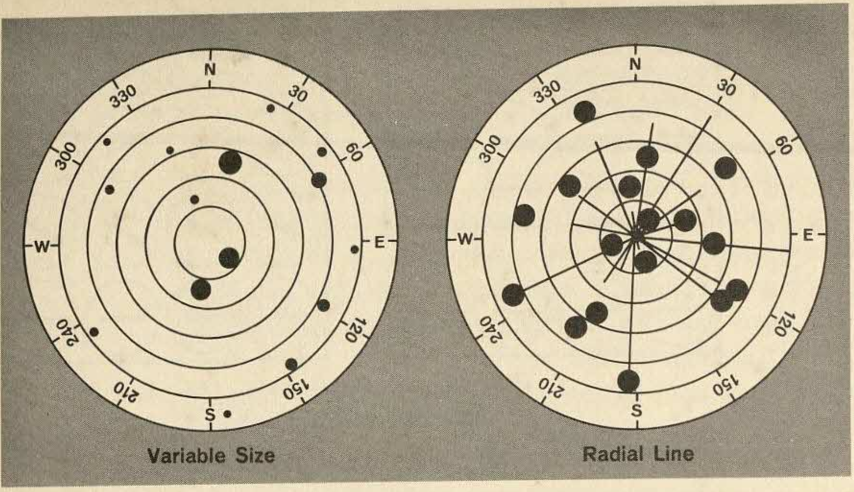


FIGURE 14.21. *Alternative methods of representing the three dimensions of bearing, range, and altitude on a two-dimensional oscilloscope display. (After Holland, G. E., and Emmons, B. W.,* Comparative tests on three-dimensional displays. *Air Materiel Command, Cambridge Field Station, Report No. 1-50, 1947)*

Simplification of the conceptual aspects of jobs can be undertaken by using signals which are maximally distinct, thus minimizing interference; and by making use of previously established concepts insofar as possible, thus capitalizing on transfer of training from previous learning. A simple example occurs in the representation of three dimensions of activity of a target on a radar scope. In several radar applications, it is desired to represent the position of a target (such as an enemy aircraft) in range, in altitude, and in bearing. Such representations cannot readily be accomplished in terms of a perceptual model, since this would require a three-dimensional display of some sort, whereas the scope face has only two. The designer therefore turns to the procedure of representing these three variables in a conceptual manner. This means he must provide "coding" which will make possible the ready identification of each dimension. Two examples of how this problem may be solved are shown in Figure 14.21. In the first of these, the "variable size display," altitude is represented by the size of the target; in the second, an additional radial line is used to indicate altitude by its length.

In modern air defense systems, radar-scope faces must be designed to represent quite a number of different dimensions of information about enemy aircraft, besides these basic variables of altitude, range, and bearing. Some of these additional variables are speed, track, whether friendly or enemy, and type of aircraft; and this is not an exhaustive list. The coding of each of these variables and presentation of the coded display requires considerable ingenuity in equipment design. It also presents an intriguing problem in job simplification.

THE DESIGN AND DEVELOPMENT OF NEW SYSTEMS

In previous sections of this chapter, we have described some ways in which knowledge of human behavior is put to use in designing equipment. When the problem is viewed as one of "fitting the equipment to the man," it is typically equipment as a *component* with which we are dealing. But now we turn our attention to the development of a *total system.* This requires consideration of the whole set of operations which the man-machine system is designed to perform. Consequently, this larger view of system design must take into account the factors which "develop" the man as well as the equipment, including particularly selection, training, and the measurement of human performance.

Whenever a new system is designed, whether it be a weapon system for the armed forces, a system for widespread public use (such as long-distance dial telephoning), or a system of production for an industry, consideration needs to be given to human performance throughout the whole cycle of development and use of the system. Engineering psychology in its broadest sense involves the application at many different points during system development of knowledge about human behavior. In every phase, decisions about the nature of the system are made which will determine the nature of human performances required, and consequently the kinds of human capacities and abilities that will be necessary when the system is used. Sometimes, these decisions are made by equipment designers on the basis of only the crudest sort of information about human behavior. Greatly increased precision can be introduced into the process of system design by utilizing more exact behavioral information, of the general categories illustrated by the material in this chapter. This in turn can increase the efficiency of the system, by saving manpower, scarce abilities, and time for training and replacement of human operators.

What kinds of information from general psychology can be applied to the process of system design, and when is this information useful? The critical phases during which psychological knowledge plays a part are outlined in Table 14.3.

In the table, the process of applying knowledge about behavior to system development is called the *development of the personnel subsystem.* This phrase is used to emphasize the integrated nature of the decisions in system development affecting personnel, their jobs, selection, and training. As we have pointed out previously, one cannot design a job efficiently without considering the alternatives provided by the use of job aids for job simplification, selection to obtain personnel with the proper combinations of abilities, or training for the acquisition of higher levels of skill over a

TABLE 14.3
APPLICATIONS OF PSYCHOLOGY TO SYSTEM DEVELOPMENT: DEVELOPMENT OF THE PERSONNEL SUBSYSTEM

Phase of System Development	*Personnel Subsystem Development*
Design Phase	Design of Operations
Development Phase	Job Design Selection and Training Job Aids Performance Assessment
Testing Phase	System Test

period of time. Simplifying the job may reduce the demands of both selection and training. Raising the standards for selection of personnel may reduce the time required for training, but may run into difficulty finding men with the degree of talent required. The whole process of designing the personnel subsystem is one in which consideration is given to every alternative method of achieving the required system performance, at every phase of system development.

Developing the Personnel Subsystem

OPERATIONS DESIGN. As Table 14.3 shows, the human being is first considered in the design phase of system development. What is designed is a set of *operations*, as we have described this process in Chapter 11. For an industrial process, the designer thinks of such operations as metal-processing, machining, assembly, inspection. When a weapon system is being designed, operations may include such things as check-out, storage, launching. These are the major *man-machine* (or *man-environment*) *interactions* which constitute the basic conception of system use. Direct considerations of human behavior are made at this stage primarily to exclude operations which would exceed human capacities, or which would be likely to require extremely scarce abilities. For example, an airplane may be designed to travel vertically with an acceleration of 20 times gravity. But a piloted aircraft system cannot, because man's capacity is exceeded.

JOB DESIGN. The functions of the system, once determined, must be assigned to various components of the system. Some crucial decisions about the division of functions between men and equipment are made at this stage. The basic design considerations outlined in the previous section are relevant to these decisions. The sensory, motor, and decision-making capacities must be kept within human limitations. Further than this, the very important goal of job simplification needs to be pursued by methods illustrated in the previous section of this chapter. Subsequent steps in the design of jobs are concerned with the process of describing and analyzing jobs, as described in Chapter 11. Looking forward to the design of selection and training procedures, job aids, and training devices, the job analysis aims at specifying the human abilities and skills required for the operation and maintenance of the system. The products of this phase of system design are descriptions of the human jobs required by the system, and a statement of required human abilities and skills.

SELECTION AND TRAINING. On the basis of job analysis, standards can now be specified for both selection and training. Those general abilities which can be economically obtained in the available population are specified for selection. Ability tests to be employed, as well as qualifying scores on tests or combinations of tests, can be stated. Previous training and experience requirements can be specified as alternatives to ability tests or in addition to them. The necessary training programs are also planned at this stage. For specific skills, the aims of training should be related in a one-to-one manner to job requirements. In achieving these aims, consideration needs to be given to the use of training aids and devices as efficient means of producing learning. In addition, the goals of training should be made specific by determining how proficiency in trained skills can best be measured.

JOB AIDS. When the development of equipment components reaches the point where prototypes are available, specifications can be laid down for the informational aids to be used *on the job*. The basic decisions about the job performances which can be supported by such aids (check lists, handbooks) have been arrived at previously in designing for job simplification. Now comes the task of defining in specific terms exactly what kinds of printed verbal cues are most helpful to the various job performances. The purpose of these aids is to make the learning of certain specific skills unnecessary. Procedural sequences, particularly lengthy ones, can readily be treated in this way. Infrequently used information (like exact hardware nomenclature) can also be provided in a handbook. Schematic or flow diagrams of equipment, when designed as job aids, also make unnecessary the learning of the concepts they represent. All of these can be specified once the detailed configuration of the equipment is known.

PERFORMANCE ASSESSMENT. Once the equipment designs have been fixed, specifications for the assessment of performance can be made. Remember that we are concerned with assessing performance in the specific tasks of the job, as defined by the job description. While choices among production measures, performance tests, job-knowledge tests, and rating methods are based partly on economic considerations, the engineering psychologist is concerned with the representativeness of the measures employed, as well as with their reliability, as pointed out in Chapter 12. The specification of performance measures is a crucial part of personnel subsystem design. Equipment often contains within itself the means of evaluating its performance over periods of time. But for men, it is essential to make provisions for controlled measurements which can identify the strengths and weaknesses of strictly human functioning. Only in this way can one obtain an indication of the success of the personnel subsystem as a whole, and obtain the clues necessary for improving it.

SYSTEM TEST. Before it is placed in full operation, every system is tested, either in a formal evaluation, as when an agency inspects a developed system before accepting it for use, or informally in preliminary "shake-down" trials. Actually, to be most useful, such tests should provide good information about the functioning of various parts (subsystems) of the total system. The personnel subsystem is no exception. But obviously, steps have to be taken to separate the functioning of the human component from that of the machine component. Performance tests of human functioning, or production measures in which the hardware functions are held at constant values, are of particular usefulness for this type of testing.

The development of the personnel subsystem can be conceived as an integrated process in which attention is paid to the human being and his performance at every phase of system development. Beginning with the early design of system operations, which determine the basic conception of system use, personnel capabilities and limitations must be taken into account. The engineering psychologist plays an important role in designing jobs which are compatible with human capabilities and with the aim of job simplification. Further than this, however, he has the responsibility of drawing out, in precisely specified terms, the implications of hardware design for selection, training, training equipment, job aids, and human performance assessment. In the testing of the system, he becomes concerned with devising procedures for the independent evaluation of human performance, as an essential part of total system effectiveness.

SUMMARY

Engineering psychology is practiced when the principles of behavioral science are put to use in the design and development of man-machine systems. The psychologist, often operating as a member of an engineering team, is concerned both with the design of the man (jobs, selection, training, etc.) and the design of equipment to fit the abilities of the man.

In the design of equipment, two major types of consideration of human performance are involved. The first is the set of human *capacities* which must not be exceeded if the system is to be successfully operated and maintained. The second is *simplifying the job,* to insure economical use of manpower, to reduce training time, and to increase proficiency on the job.

Many investigations in the field of engineering psychology have been aimed at determining the limits of human capacities with reference to the operation of some new piece of equipment. Military equipment, since it is constantly changing to meet new defense requirements, provides many good examples of the application of these findings. New equipment must keep within the limitations of human sensory, motor, and learning capacities, as well as within limits imposed by the physical dimensions of the human body.

Job simplification has the specific purposes of insuring the lowest possible standards for selection tests, in order to draw personnel from the widest population of manpower, and of reducing the time required for training. Jobs may be simplified in a number of different ways, particularly by (a) substituting tasks requiring different abilities or patterns of abilities which are more readily available; (b) reducing the length and complexity of tasks; and (c) providing accessory job aids which give stimulus support to performances on the job.

The most comprehensive application of psychological principles is seen in system design and development. Events in the typical sequence of design, development, and test of equipment subsystems are paralleled by and interact with the development of the *personnel subsystem.* The latter begins, during the design phase, with general considerations of human capacity limitations for the operations to be required. During development of the system, the design of jobs in accordance with human engineering principles is a basic step preceding the description and analysis of jobs, and the derivation from them of specifications for selection, training, job aids, and proficiency assessment. Evaluation of the system as a whole necessitates the separate control and measurement of human performances during the system test, in order to distinguish "hardware" errors from "human" ones.

READING REFERENCES

———, *Handbook of human engineering data for design engineers.* USN Special Devices Center Technical Report SDC 199-1-1, 1949. A basic handbook summarizing data on human capacities and skills, for application to the design of equipment.

Chapanis, A., *The design and conduct of human engineering studies.* San Diego, California: San Diego State College Foundation, 1956. A book

about scientific methods and their use in studying the problems of engineering psychology.

Chapanis, A., Garner, W. R., and Morgan, C. T., *Applied experimental psychology*. New York: Wiley, 1949. A textbook of methods of experimental psychology and their application in equipment design studies.

Fitts, P. M. Engineering psychology and equipment design, Ch. 35 in S. S. Stevens (Ed.), *Handbook of experimental psychology*. New York: Wiley, 1951. An account of the problems and methods of engineering psychology, providing a summary of some important findings relevant to equipment design.

McCormick, E. J., *Human engineering*. New York: McGraw-Hill, 1958. A textbook of engineering psychology, summarizing evidence about human capacities and job simplification.

REFERENCES AND INDEXES

REFERENCES CITED IN THE TEXT

The following books and articles are references for statements made in the text. The number preceding each reference is the superscript number used in the corresponding chapter of the book; the number in parentheses indicates the text page reference. References which are given under the figures and tables in the text are not repeated here.

CHAPTER 1

Introduction: The Science of Behavior

1.(8) Mowrer, O. H., Rayman, N. N., and Bliss, E. L., Preparatory set (expectancy)—an experimental demonstration of its "central" locus. *J. exp. Psychol.*, 1940, *26*, 357-372.

CHAPTER 2

Basic Components of Behavior

1.(19) Morgan, C. T., and Stellar, E., *Physiological psychology* (2nd Ed.). New York: McGraw-Hill, 1950, Chapter IX.

2.(22) Woodworth, R. S., and Schlosberg, H., *Experimental psychology* (Rev. Ed.). New York: Holt, 1954, Chapter 2.

CHAPTER 3

Functions of the Behavior System

No references, other than those with the figures and tables in the text.

CHAPTER 4

Motivation

1.(57) Delgado, J. M. R., and Anand, B. K., Increase of food intake induced by electrical stimulation of the lateral hypothalamus. *Amer. J. Physiol.*, 1953, *172*, 162-168.

2.(57) Anand, B. K., and Brobeck, J. R., Localization of a "feeding center" in the hypothalamus of the rat. *Proc. Soc. exp. biol. Med.*, 1951, *77*, 323-324.

3.(57) Davis, C. M., Self selection diet by newly weaned infants. *Am. J. dis. Childr.*, 1928, *36*, 651-679.

4.(57) Richter, C. P., The internal environment and behavior: Internal secretions. *Amer. J. Psychiat.*, 1941, *97*, 878-893.

5.(58) Adolph, E. F., The internal environment and behavior: Water content. *Amer. J. Psychiat.*, 1941, *97*, 1365-1373.

6.(62) Harlow, H. F., Motivational forces underlying learning. In *Kentucky Symposium: Learning theory, personality theory, and clinical research.* New York: Wiley, 1954.

7.(62) Bexton, W. R., Heron, W., and Scott, R. H., Effects of decreased variation in the sensory environment. *Can. J. Psychol.*, 1954, *8*, 70-76.

8.(62) Stellar, E., The physiology of motivation. *Psychol. Rev.*, 1954, *61*, 5-22.

9.(64) Rowan, W., *The riddle of migration.* Baltimore: Williams and Wilkins, 1931.

10.(64) Roule, L., *Fishes: their journeys and migrations.* New York: Norton, 1933.

11.(68) Watson, J. B., and Rayner, R., Conditioned emotional reactions. *J. exp. Psychol.*, 1920, *3*, 1-14.

12.(69) Roethlisberger, F. J., and Dickson, W. J., *Management and the worker.* Cambridge, Mass.: Harvard Univ. Press, 1939.

13.(70) Haire, M., *Psychology in management.* New York: McGraw-Hill, 1956.

14.(71) McClelland, D. C., Atkinson, J. W., Clark, R. A., and Lowell, E. L., *The achievement motive.* New York: Appleton-Century-Crofts, 1953.

15.(72) Gould, R., An experimental analysis of "level of aspiration." *Genet. Psychol. Monogr.*, 1939, *21*, 3-115.

16.(78) Lewin, K., Group decision and social change. In *Readings in* *social psychology* (ed. by Newcomb, T. M., and Hartley, E. L.). New York: Holt, 1947.

17.(79) Same as reference 16.

18.(80) Book, W. F., and Norvell, L., An experimental study of learning incentives. *Ped. Sem.*, 1922, *29*, 305-362.

19.(80) Mowrer, O. H., Social modification of organically motivated behavior. Pennsylvania State College, Psychological Cinema Register, Film No. PCR-24.

20.(81) Maller, J. B., *Cooperation and competition* (Contribution to Education No. 384). New York: Teachers College, Columbia Univ., 1929.

CHAPTER 5

Human Abilities

1.(96) Anastasi, A., *Differential psychology.* New York: Macmillan, 1957.

2.(97) Hayes, K. J., and Hayes, Catherine, The intellectual development of a home-raised chimpanzee. *Proc. Amer. phil. Soc.*, 1951, *95*, 105-109.

3.(98) Zingg, R. M., Feral man and extreme cases of isolation. *Amer. J. Psychol.*, 1940, *53*, 487-517.

4.(98) Havighurst, R. J., and Breese, F. H., Relation between ability and social status in a midwestern community: III. Primary mental abilities. *J. educ. Psychol.*, 1944, *35*, 357-368.

Janke, L. L., and Havighurst, R. J., Relations between ability and social status in a midwestern community: II. Sixteen-year-old boys and girls. *J. educ. Psychol.*, 1945, *36*, 499-509.

5.(98) Brown, F., A comparative study of the intelligence of Jewish and Scandinavian kindergarten children. *J. genet. Psychol.*, 1944, *64*, 67-92.

Held, O. C., A comparative study of the performance of Jewish and gentile college students on the American Council Psychological Examination. *J. soc. Psychol.*, 1941, *13*, 407-411.

Bere, M. A., Comparative study of mental capacity of children of foreign parentage. *Teach. coll. Contr. Educ.*, No. 154, Columbia Univ., 1924.

6.(101) Hempel, W. E., and Fleishman, E. A., A factor analysis of physical proficiency and manipulative skill. *J. appl. Psychol.*, 1955, *39*, 12-16.

7.(119) French, J. W., The description of aptitude and achievement tests in terms of rotated factors. *Psychometric Monogr.*, No. 5, Univ. of Chicago Press, 1951.

8.(119) Thurstone, L. L., Some primary abilities in visual thinking. *Psychometric Lab.*, No. 59, Univ. Chicago, August 1950.

Fleishman, E. A., Roberts, M. M., and Friedman, M. P., A factor analysis of aptitude and proficiency measures in radio-telegraphy. *J. appl. Psychol.*, 1958, *42*, 129-135.

9.(120) Michael, W. B., Guilford, J. P., Fruchter, B., and Zimmerman, W. S., The description of spatial-visualization abilities. *Educ. Psychol. Measmt.*, 1957, *17*, 185-199.

10.(121) Fleishman, E. A., Roberts, M. M., and Friedman, M. P., A factor analysis of aptitude and proficiency measures in radio-telegraphy. *J. appl. Psychol.*, 1958, *42*, 129-135.

11.(122) Guilford, J. P., The structure of intellect. *Psychol. Bull.*, 1956, *53*, 267-293.

12.(122) Kelley, H. P., A factor analysis of memory ability. Ph.D. thesis, Princeton Univ., 1954.

13.(123) Guilford, J. P., and Lacey, J. I. (Eds.), *Printed classification tests.* AAF Aviation psychology program, Research Report No. 5, Washington, D. C.: Govt. Printing Office, 1947.

14.(125) Fleishman, E. A., Psychomotor selection tests: research and application in the U.S. Air Force. *Pers. Psychol.*, 1956, *9*, 448-467.

Fleishman, E. A., Dimensional analysis of movement reactions. *J. exp. Psychol.*, 1958, *55*, 438-453.

Fleishman, E. A., Dimensional analysis of psychomotor abilities. *J. exp. Psychol.*, 1954, *48*, 437-454.

Fleishman, E. A., and Hempel, W. E., Factorial analysis of complex psychomotor performance and related skills. *J. appl. Psychol.*, 1956, *40*, 96-104.

15.(127) Hempel, W. E., and Fleishman, E. A., A factor analysis of physical proficiency and manipulative skill. *J. appl. Psychol.*, 1955, *39*, 12-16.

16.(127) Fleishman, E. A., and Hempel, W. E., A factor analysis of dexterity tests. *Pers. Psychol.*, 1954, *7*, 15-32.

17.(127) Same as reference 15.

18.(128) Adams, J. A., *An evaluation of test items measuring motor abilities.* Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, Research Report AFPTRC-TN-56-55, 1956.

19.(129) Carroll, J. B., A factor analysis of verbal abilities. *Psychometrika*, 1941, *6*, 279-308.

20.(129) Guilford, J. P., The structure of intellect. *Psychol. Bull.*, 1956, *53*, 267-293.

21.(129) French, J. W., The description of aptitude and achievement tests in terms of rotated factors. *Psychometric Monogr.*, No. 5, Univ. of Chicago Press, 1951.

22.(129) Same as reference 20.

23.(131) French, J. W. (Ed.), *Kit of selected tests for reference aptitude and achievement factors.* Princeton, N. J.: Educational Testing Service, 1954.

CHAPTER 6

Learning and Retention

1.(146) Pavlov, I. P., *Conditioned reflexes.* Trans. G. V. Anrep. New York: Oxford Univ. Press, 1927.

2.(151) Gagné, R. M., and Graham, C. H., The effect of an "emotional state" on the initial stages of acquisition in a conditioned operant response. *Proc. Nat. Acad. Sci.*, 1940, *26*, 297-300.

3.(167) Hendrickson, G., and Schroeder, W. H., Transfer of training in learning to hit a submerged target. *J. educ. Psychol.*, 1941, *32*, 205-213.

4.(174) Underwood, B. J., Interference and forgetting. *Psychol. Rev.*, 1957, *64*, 49-60.

CHAPTER 7

Discrimination and Identification

1.(194) Hardy, J. D., Wolff, H. G., and Goodell, H., Studies on pain: discrimination of differences in intensity of a pain stimulus as a basis of a scale of pain intensity. *J. clin. Invest.*, 1947, *26*, 1152-1158.

2.(196) James, W., *Principles of psychology.* New York: Holt, 1890.

3.(196) Riesen, A. H., The development ot visual perception in man and chimpanzee. *Science*, 1947, *106*, 107-108.

4.(211) Worchel, P., and Dallenbach, K. M., "Facial vision": perception of obstacles by the deaf-blind. *Amer. J. Psychol.*, 1947, *60*, 502-553.

5.(216) Kennedy, J. L., and Lasswell, H. D., A cross-cultural test of self-image. *Hum. Organiz.*, 1958, *17*, 41-43.

CHAPTER 8

Motor Skills

1.(223) Miles, D. W., Preferred rates in rhythmic response. *J. gen. Psychol.*, 1937, *16*, 427-469.

2.(227) Seashore, S. H., and Seashore, R. H., Individual differences in simple auditory reaction times of hands, feet and jaws. *J. exp. Psychol.*, 1941, 29, 342-345.

3.(227) Same as reference 2.

4. (227) Same as reference 2.

5. (227) Baxter, B., A study of reaction time using factorial design. *J. exp., Psychol.*, 1942, *31*, 430-437.

6. (227) Johanson, A. M., The influence of incentive and punishment upon reaction time. *Arch. Psychol.*, 1922, No. 54.

7. (228) Katzell, R. A., Relations between the activity of muscles during preparatory set and subsequent overt performance. *J. Psychol.*, 1948, *26*, 407-436.

8. (229) (a) Provins, K. A., Effect of limb position on the forces exerted about the elbow and shoulder joints on the two sides simultaneously. *J. appl. Physiol.*, (N.B.) 1955, 7, 387-389.

(b) Provins, K. A., Maximum forces exerted about the elbow and shoulder joints on each side separately and simultaneously. *J. appl. Physiol.*, (N.B.) 1955, 7, 390-392.

9. (230) Provins, K. A., and Salter, N., Maximum torque exerted about the elbow joint. *J. appl. Physiol.*, (N.B.) 1955, 7, 393-398.

10. (230) Elfel, E. R., Relationships between leg strength, leg endurance, and other body measurements. *J. appl. Physiol.*, 1949, *2*, 197-207.

11. (230) Hunsicker, P. A., *Arm strength at selected degrees of elbow flexion.* Wright Air Development Center, Technical Report 54-548, August 1955.

12. (240) James, W., *Principles of psychology.* New York: Holt, 1890.

13. (253) Adams, J. A., and Reynolds, B., Effect of shift in distribution of practice conditions following interpolated rest. *J. exp. Psychol.*, 1954, *47*, 32-36.

CHAPTER 9

Concepts and Thinking

1. (271) Thurber, James, The secret life of Walter Mitty. In *My world and welcome to it.* New York: Harcourt, Brace, 1942.

2. (273) Welch, L., and Long, L., The higher structural phases of concept formation of children. *J. Psychol.*, 1940, 9, 59-95.

3. (285) Katona, G., *Organizing and memorizing.* New York: Columbia Univ. Press, 1940.

4. (288) Luchins, A. S., Mechanization in problem solving: the effect of Einstellung. *Psychol. Monogr.*, 1942, *54*, No. 248.

CHAPTER 10

Social Behavior

1. (294) Linton, R., *The cultural background of personality.* New York: Appleton-Century, 1945.

2.(295) Benedict, R., *Patterns of culture.* Boston: Houghton Mifflin, 1934.

3.(303) Roethlisberger, F. J., and Dickson, W. J., *Management and the worker.* Cambridge, Mass.: Harvard Univ. Press, 1939.

4.(307) Sherif, M., A study of some social factors in perception. *Arch. Psychol.,* 1935, No. 187.

5.(308) Hemphill, J. K., and Westie, C. M., The measurement of group dimensions. *J. appl. Psychol.,* 1950, *29,* 325-342.

6.(311) Moreno, J. L., *Who shall survive?* Washington, D. C.: Nervous and Mental Disease Publishing Co., 1934.

7.(313) Van Zelst, R. H., Sociometrically selected work teams increase production. *Pers. Psychol.,* 1952, *5,* 175-185.

8.(314) Leavitt, H., *Managerial psychology.* Chicago: Univ. Chicago Press, 1958.

9.(318) Stogdill, R. M., Personal factors associated with leadership: a survey of the literature. *J. Psychol.,* 1948, *25,* 35-71.

10.(319) Tannenbaum, R., *Helping managers become more effective leaders.* Speech presented at third seminar on social science for industry. Stanford Research Institute, 1955.

11.(320) Lewin, K., Lippitt, R., and White, R. K., Patterns of aggressive behavior in experimentally created social climates. *J. soc. Psychol.,* 1939, *10,* 271-299.

12.(322) Hemphill, J. K., *Leader behavior description.* Columbus, Ohio: Personnel Research Board, Ohio State Univ., 1950.

13.(324) Halpin, A. W., and Winer, B. J., A factorial study of the leader behavior descriptions. In Stogdill, R. M., and Coons, A. E., *Leader behavior: its description and measurement.* Columbus, Ohio: Bureau of Business Research, Ohio State Univ., 1957.

14.(325) Rush, C. H., Jr., Leader behavior and group characteristics. In Stogdill, R. M., and Coons, A. E., *Leader behavior: its description and measurement.* Columbus, Ohio: Bureau of Business Research, Ohio State Univ., 1957.

15.(325) Fleishman, E. A., Harris, E. F., and Burtt, H. E., *Leadership and supervision in industry.* Columbus, Ohio: Bureau of Educational Research, Ohio State Univ., 1955.

16.(326) Halpin, A. W., The leader behavior and effectiveness of aircraft commanders. In Stogdill, R. M., and Coons, A. E., *Leader behavior: its description and measurement,* Columbus, Ohio: Bureau of Business Research, Ohio State Univ., 1957.

17.(326) Hemphill, J. K., Leader behavior associated with the administrative reputations of college departments. In Stogdill, R. M., and Coons,

A. E., *Leader behavior: its description and measurement*, Columbus, Ohio: Bureau of Business Research, Ohio State Univ., 1957.

18.(326) Kahn, R. L., and Katz, D., Leadership practices in relation to productivity and morale. In Cartwright, D., and Zander, A. (Eds.), *Group dynamics*. Evanston, Ill.: Row, Peterson, 1953.

19.(326) Katz, D., Maccoby, N., and Morse, N. C., *Productivity, supervision and morale in an office situation.* Ann Arbor, Mich.: Survey Research Center, Univ. of Michigan, 1950.

20.(327) Fleishman, E. A., Harris, E. F., and Burtt, H. E., *Leadership and supervision in industry.* Columbus, Ohio: Bureau of Educational Research, Ohio State Univ., 1955.

21.(331) Worthy, J. C., Organizational structure and employee morale. *Amer. sociol. Rev.*, 1950, *15*, 169-179.

22.(334) Adapted from Maier, N. R. F., *Psychology in industry.* Boston: Houghton Mifflin, 1946.

23.(335) Sherif, M., An experimental study of stereotypes. *J. abnorm. and soc. Psychol.*, 1935, *29*, 371-375.

24.(335) Hayakawa, S. I., *Language in action.* New York: Harcourt, Brace, 1939.

CHAPTER 11

Jobs and Personnel Selection, I

1.(358) Guilford, J. P., and Zimmerman, W. S., *The Guilford-Zimmerman Temperament Survey: Manual.* Beverly Hills, Calif.: Sheridan Supply Co., 1949.

2.(359) Strong, E. K., Jr., *Vocational interests of men and women.* Stanford, Calif.: Stanford Univ. Press, 1943.

3.(359) Kuder, G. F., *Manual to the Kuder Preference Record.* Chicago: Science Research Associates, 1946.

CHAPTER 12

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No references, other than those with the figures and tables in the text.

CHAPTER 13

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1.(402) Fleishman, E. A., Leadership climate, human relations training, and supervisory behavior. *Pers. Psychol.*, 1953, *6*, 205-222.

2.(406) Knower, F. H., Experimental studies of changes in attitude: I. A study of the effect of oral argument on changes in attitude. *J. soc. Psychol.,* 1935, *6,* 315-347.

Knower, F. H., Experimental studies of changes in attitude: II. A study of the effect of printed argument on changes in attitude. *J. abnorm. soc. Psychol.,* 1936, *30,* 522-532.

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